MAY 1960

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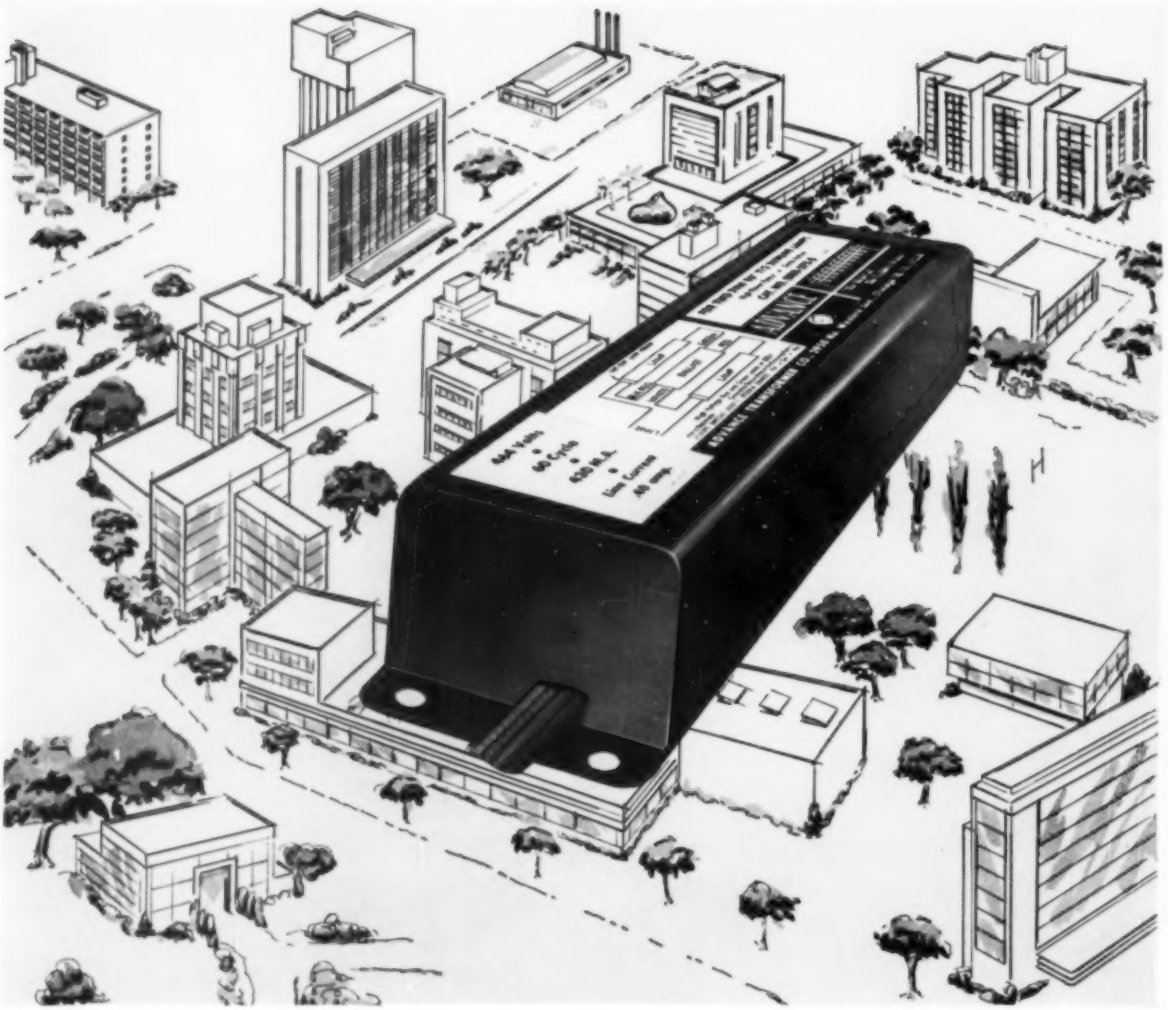
ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY



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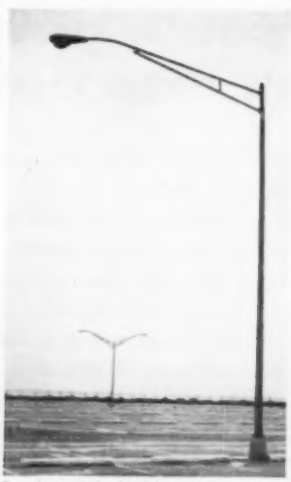

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Roadway Plazas

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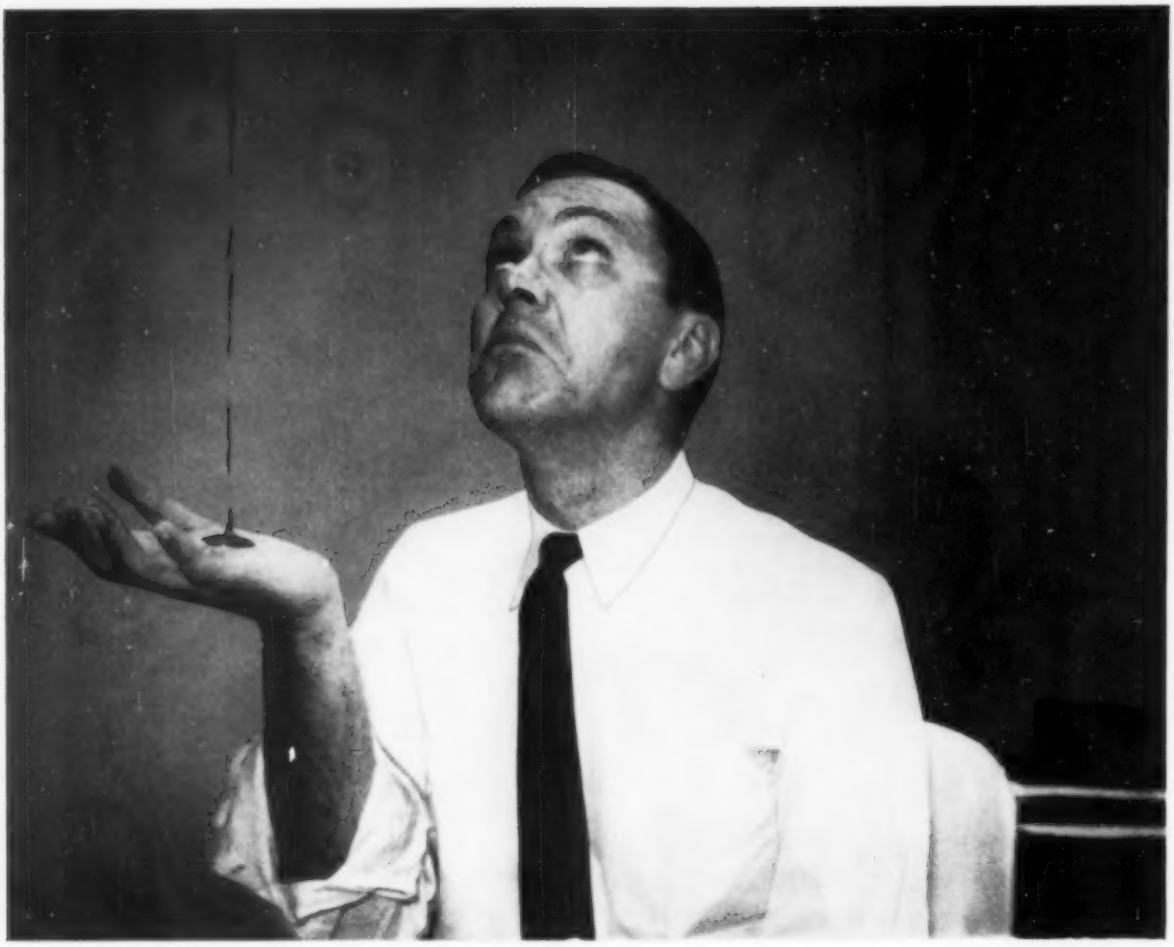

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May
1960

Vol. LV, No. 5

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Personnel and Products Get High Lighting Utility at This Utility

INSTALLATION: Cape & Vineyard Electric Company, Falmouth, Massachusetts
AREA SHOWN: Showroom and Office
ARCHITECT: Hillman & Wilson, Falmouth, Massachusetts
ENGINEER: Joseph Smith and Ned Hudson, Cape & Vineyard Electric Co.
ELECTRICAL CONTRACTOR: Quinn Electric Company, Falmouth, Massachusetts
DISTRIBUTOR: Finberg Supply Company, Lawrence, Massachusetts
DISTRICT SALES ENGINEER FOR LITECONTROL CORPORATION: Dallas G. Dearmin, 5 Hillcrest Avenue, Greenville, Rhode Island
FIXTURES: 1 — Luminous Lens Ceiling, using Holophane #6024 acrylic lenses, 40 watt Rapid Start strip fixtures on 24" centers. 1 — Luminous Ceiling using yellow Plastic Grid Louvers, 45° x 45° shielding; 40 watt Rapid Start strip fixtures 12" on centers, wired on dimming ballasts. Series 1500 two lamp Rapid Start troffers, using Holophane #6010 Concave Acrylic Lenses, in balance of area.
CEILING HEIGHT: Approximately 10 feet
INTENSITY: Average overall, approximately 200 foot-candles in service.

Perhaps this showroom and office of the Cape & Vineyard Electric Company can't compete with the scenic wonders of Cape Cod. But in the area of interior commercial lighting, the efficiency of this installation deserves a second look.

Note how luminous ceiling panels have been dropped 10" and framed to simulate a large area surface fixture. This is an imaginative and practical way of using lens ceilings where the ceiling cannot be lowered and demonstrates the flexibility of Litecontrol luminous ceiling systems. In the showroom, yellow plastic grid louvers provide color as well as an excellent intensity level which is variable by means of dimming ballasts and controls. Our series 1500 low-brightness lens troffers, with Holophane #6010 concave acrylic lens is also used. The shape keeps brightness down, maintains efficiency.

These fixtures are carefully designed and built for rigidity and good alignment. See the way troffers and ceiling panels are installed in perfectly straight lines. See *your* way to quality lighting at lower cost with Litecontrol.

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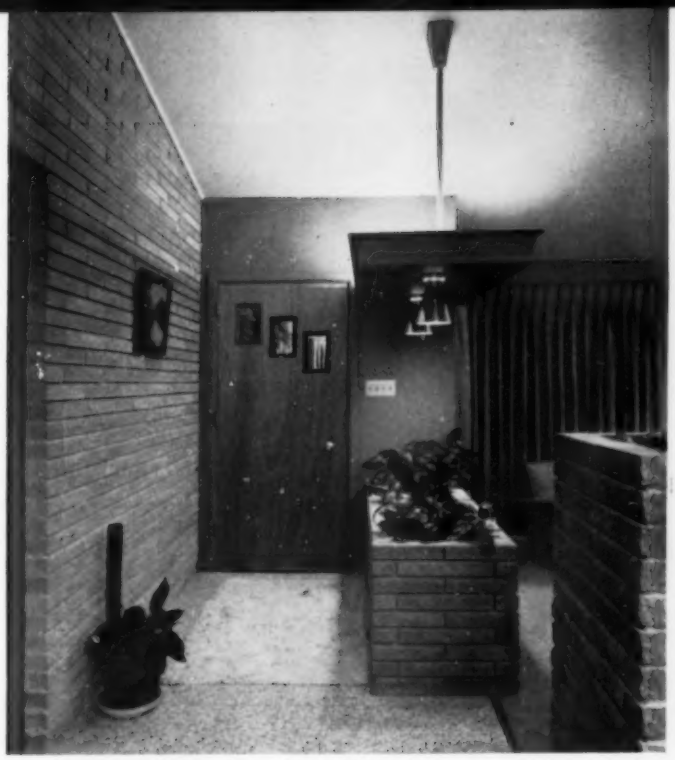
36 Pleasant Street, Watertown 72, Massachusetts

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

A. C. Mumme Home,
George West, Texas



"Light panel" with two 40-inch and four 24-inch fluorescent strips diffusing light over the entranceway and emphasizing the high ceiling provides a warm welcome for the visitor. Two perforated brass cone-shaped fixtures with 150-watt lamps spotlight the planter and add decorative interest.

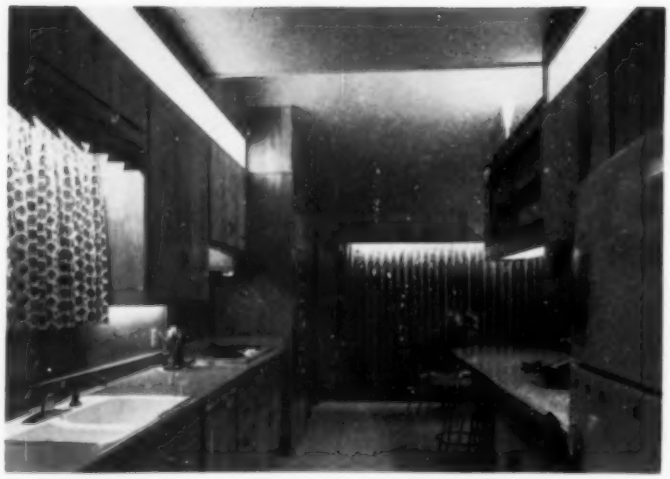
Lighting To Live By

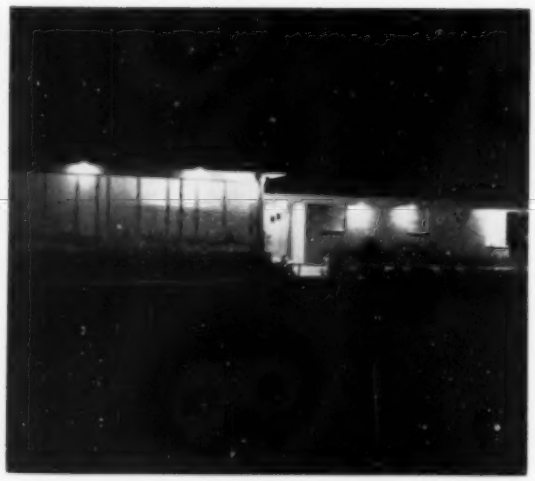
IN THE home, where the value of quality lighting cannot be measured in terms of increased production, fewer rejects or greater volume of business, lighting is often considered subservient to decorative scheme, with portable lamps and fixtures chosen for their contribution to décor rather than to luminous environment. To the residential lighting designer, this is indeed a challenge—to prove that good lighting is at once functional and decorative, providing an optimum seeing environment, adding another dimension to décor. In the two homes shown, on this page and the two that follow, one belonging to outdoorsmen living in Texas ranch country, the other to a family of artists in Baltimore, lighting blended with architecture and interior design has enhanced the "personality" of the home and provided comfortable visual environment. Lighting for the Mumme home was designed by Virginia Benson, Central Power and Light Co., Sinton, Texas. Simon E. Ehrlich, Excello Public Service Corp., Baltimore, Md., is responsible for the Weinberger's lighting scheme.

In the living room the cluster of ceiling-mounted fixtures in the far corner gives localized illumination and contributes to decorative balance; the light panel provides diffuse illumination on ceiling. Two decorative pendent units mounted over second planter, separating family room and living room (shown in photo of family room on next page), are used for accent lighting on the planter.

Through the center of the home, 29 feet of cove lighting from seven 48-inch fluorescent strips diffuses illumination across ceiling in family room and kitchen. On the window wall of the family room (see photo below), a 26-foot cornice dramatizes the long expanse of draperies with light. In the glassware cabinet, which serves as an effective room divider between family room and kitchen, a 48-inch fluorescent strip mounted on top supplements the light diffused on the ceiling by the cove; soffit lighting beneath cabinet provides illumination on eating bar.

Kitchen area has side soffit lighting installed above the cabinets — three 40-watt fluorescent channels on one side of the room, two 40-watt fluorescent channels opposite for cross illumination. Centered above the sink are two 30-watt fluorescent lamps shielded by a face board, which together with one 40-watt and two 30-watt fluorescent lamps mounted under the cabinets provide an even distribution of 45-foot-candles over the entire work surface.





Outdoor living, an integral part of country life, is made pleasant by 22 incandescent fixtures carefully placed to brighten outdoor living area (left) or display the exterior of the home for easy identification at night.

Weinberger Home, Baltimore, Maryland

Designed with lumen counter method (minimum of 75 lamp lumens per square foot of room area), lighting in this home is combination of wall brackets and recessed ceiling equipment with formed white diffusers extending below ceiling line. In the kitchen, for example, four wall brackets supply comfortable light over work areas, four recessed units are used for general illumination. Downlights in range hood give direct light on work area.

Gallery (or hallway) is where the family's paintings are displayed under light coming from a wall bracket. To achieve the desired effect in this section of the house, the fluorescent lamp channels have been placed on the bracket board to direct more light onto the wall and, consequently, onto the paintings.

Fluorescent wall bracket extending along dining room and living room wall is a unifying decorative element supplying diffuse general illumination flowing from room to room. The owners of this house particularly requested a bracket instead of a valance to create a feeling of light being diffused from this non-window wall after dark. Wicker sphere over dining table is keyed to contemporary Far East décor.

Family room has four recessed luminaires for general illumination, pole lamp to display changing art exhibit on back wall. This is the only room in the house without a wall bracket. In the living room (not shown) a wall bracket in combination with portable lamps supplies diffuse general illumination and reading light. A specially designed recessed light with pin-hole aperture is used to highlight a painting on the stone fireplace wall. In the bedroom (above) the bracket is used as a decorative element, supplying modeling illumination for the stone wall. For functional reading light, portable lamps are placed on each side of the bed.

I.E.S. LIGHTING DATA SHEET 8-9

INSTALLATION AT JOHN E. MEYER & SON, 1233 SUMMER ST., PHILADELPHIA, PA.

Lighting a Monotype Casting Room

LIGHTING OBJECTIVE: To provide a high level of diffuse illumination for the operation of Monotype casting machines.

GENERAL INFORMATION: The area shown above is approximately 18 feet by 22 feet, with a 12-foot ceiling height. Exhaust hoods are located above each machine to remove heat and to maintain a clean atmosphere in the area. Colors and reflectances of room surfaces are:

ceiling	white	80% RF	floor	concrete	30% RF
walls, upper	white	80% RF	machines	gray	30% RF
lower	gray	28% RF			

INSTALLATION: Three continuous rows of luminaires suspended on 7-foot centers provide an average level of 110 footcandles after about 800-hours use. Each row, which is chain mounted 9 feet above the floor, consists of two Day-Brite Lighting, Inc., catalog No. 91252-8 8-foot units and one catalog No. 41252-4 4-foot units. Each of the 8-foot units is equipped with two 96-inch T-12 warm white slimline lamps operated at 425 ma. Each of the 4-foot units is equipped with two 40-watt T-12 rapid start warm white fluorescent lamps. Both 4-foot and 8-foot units are industrial types providing a 25 per cent upward component of light and are equipped with louvers for 35-degree crosswise and 20-degree lengthwise shielding. Brightness readings at the 800-hour period were:

ceiling	28 fL	floor	26 fL
walls		machines	24 fL
upper	40 fL	luminaires, 45 degrees crosswise	1800 fL
lower	14 fL	45 degrees lengthwise	2000 fL

Lighting designed by James R. Rodisch, Philadelphia Electric Co., Philadelphia, Pa.

Lighting data submitted by James R. Rodisch and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa. as an illustration of good lighting practice and to aid in the design of similar installations.

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Series XXIV
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A.I.A. File No. 31 f

Remodeling with Light

In six widely different installations, some completely remodeled, others where only the illumination system has been changed, the lighting is a major tool in achieving the "new look."

Printing Plant

For the critical visual tasks performed in the printing industry under the difficult conditions of reflected glare from inked type, greasy plates (in offset printing) and wet proofs, good lighting is a necessity for minimizing errors and increasing comfort. Recent research has shown that the optimum visual conditions in a printing plant are produced by large area, high brightness (a minimum of 3000 fL) sources with at least a ten per cent upward component.

In the modernization of the lighting in the 35-year-old plant of the Drake Press, Philadelphia, the lighting engineer, guided by research findings, used low-mounted, high brightness sources to produce the necessary level of illumination and *brightness* for ease in seeing. (Type, for example, is seen by the specular reflection which produces the necessary contrast between type face and shoulder.)

Lighting design for the plant specified continuous rows of 96-inch two-lamp 800-ma rapid start industrial luminaires with 10 per cent upward component and porcelain reflectors. Fixtures are mounted on eight-foot centers, nine feet above the floor. Over the make-up tables where lines of type, cuts, ornaments, etc., are assembled to make a page, extra units were installed for a higher level of illumination. In the pressroom, fixtures are installed crossing the presses instead of in the usual parallel-to-press pattern, resulting in the absence of shadows in critical areas, complete coverage on the press top for careful inspection of the job being printed and a high level of lighting for maintenance Cool white fluorescent lamps are used throughout the installation — in the plant, design studio and offices — for consistency in color appraisal work.

Illumination levels at the Drake Press exceed the IES recommendations with 140-150 footcandles on the composition tables, 130-140 fc through the center of the pressroom, 120 at the sides of the room and 100 at the ends of the luminaire rows. Even more vital than these footcandles readings, however, is the reported comfort of the installation. Employees questioned about the relighting report no troublesome glare from the high brightness lamp at the comparatively low mounting.

Drake Press, Philadelphia, Pa.
Lighting designed by G. T. Anderson, Philadelphia Electric Co., Philadelphia, Pa.
Philadelphia Section, Third Prize

Electric Building Showroom

The proverbial "picture worth a thousand words" has become the most effective lighting salesman at Omaha Public Power District, Omaha, Nebraska, since the remodeling and relighting of the first floor showroom in the utility's Electric Building. The project was planned to bring advanced lighting practices to the attention of merchants and the public, to prove that high levels, if properly controlled, do not mean "too much light." As if to prove the advisability of this approach, the completion of the modernization program has been followed by high praise from customers and employees alike.

The Electric Building's street-level floor is a combination appliance display and customer service and sales area, originally with a 21-foot ceiling and 40 to 90 footcandles of unbalanced lighting (see cut). In the complete remodeling of the area, the ceiling was reduced to 14 feet in the display section, 8 feet in the sales and service section and a lighting system designed to give in excess of 200 fc of balanced-brightness illumination.

As is typical in remodeling jobs, the illumination system had to be arranged to accommodate existing columns, outlets for heating, air conditioning and the sprinkler system. New lighting, recessed in the T-bar ceiling, is composed of two- by four-foot and two- by eight-foot two-lamp luminaires with low brightness acrylic lenses and hinged frames for easy maintenance. In the customer service area, 92 two- by four-foot units with 40-watt T12 rapid start cool white deluxe fluorescent lamps provide an average maintained illumination intensity of 220 footcandles. The display area is lighted to a maintained level of 250 footcandles with 180 two- by eight-foot units with 96T12 430-ma slimline cool white deluxe lamps.

An interesting effect is the extension of the lighting through the showroom windows to the outdoor arcade. Here, 48 two- by eight-foot luminaires with 96T12 800-ma (for low-temperature operation) cool white rapid start lamps produce 350 footcandles on the sidewalk, an inevitable attraction for the passing crowds.

Comfort was a major consideration with the high illumination levels obtained in this installation and brightness readings show this goal was achieved. Average fixture brightness in the 75- to 90-degree zone from nadir, viewing both crosswise and endwise, is 180 fL for the interior equipment, 250 fL for the exterior equipment.

The new lighting has proved to be a major attraction in the Electric Building, setting the example as is proper for the public utility to do.

Electric Building, Omaha Public Power District, Omaha, Nebr.
Lighting designed by W. M. Scholes and Ben Civin, Omaha Public Power District, Omaha, Nebr.
Cornhusker Section, Second Prize

Toledo Edison Co., Acme Generating Station,
Toledo, Ohio.
Lighting designed by Jack Felkey, Toledo Edison Co.,
Toledo, Ohio.
Northwestern Ohio Section, First Prize

Generating Station Control Room

Pictured at left, above, is the 20-year-old lighting system of the control room of Toledo Edison Company's Acme Generating Station, a system of concentric ring, indirect, silver-bowl luminaires, intended to supply adequate general illumination on the work plane and vertical illumination on the control boards. In reality, there were 25-30 footcandles of very spotty illumination on the work plane, with vertical illumination varying from 25 down to 10 footcandles. Adding to the discomfort of the installation were specular reflections from the point source of light, reflected from the ceiling onto the dial faces on the control board.

The obviously urgent remodeling of the lighting was to provide a minimum of 50 footcandles of general illumination, 50 footcandles on the vertical panel boards, low brightness (450-500 fL or less unit brightness) with uniform distribution of light throughout the room. For economy reasons, the old ceiling was to remain unchanged, with the new lighting designed to conform to the original ceiling suspension system.

In relighting, a two-part system was designed in the shape of an arc described on the ceiling, four feet shorter in radius than the arc described on the floor by the control board. For general illumination, four-lamp surface-mounted, two- by four-foot and two- by eight-foot plastic enclosed fluorescent luminaires were installed along the lines of the imaginary 16-foot arc, on eight-foot centers, six feet four inches from the side walls. To provide vertical illumination on the panel board, a one- by ten-inch baffle board, in four-foot sections, was dropped from the ceiling and fitted with aluminum track or "U" channels, mounted on the lower face of the baffle, facing the control panel. A second track was mounted on the ceiling 10 inches from the baffle, forming a series of sections of four-foot parallel track. Four-foot four-lamp rapid-start fluorescent channels were installed on the ceiling, adjacent to the baffle board. For diffusing media, three 16-inch wide "V"-shaped .025-inch thick plastic panels were inserted under compression in the track in each four-foot module, a total of seven such sections used for the 28-foot arc of panel board lighting.

To ensure the unhindered operation of the control room in case of a power outage, an emergency d-c lighting system was needed. For this, a d-c circuit was incorporated behind the baffle board and 100-watt filament lamps placed on four-foot centers behind the "V"-shaped plastic panels. This arrangement enables the emergency filament lighting to utilize the shielding media supplied for the fluorescent system under normal operating conditions. In addition, a 200-watt incandescent unit with a diffusing lens is surface-mounted over the desk and master control panel.

Results of the relighting were 105 footcandles on the work plane (double the IES recommendation for this area), 95 footcandles, vertical, on the panel board and uniform brightness ratios. Specular reflections were eliminated from the dial faces and fine details can now be distinguished on the dial scales from any point in the room. Fixture brightnesses were held to IES recommendations and venetian blinds installed at the windows for control of daylight. Finally, the system proved economical for the company; comfortable and efficient for the employees.

Gaynes Residence, Detroit, Mich.
Lighting designed by Marian Amsbary,
Detroit Edison Co., Detroit, Mich.
Michigan Section, First Prize

Recreation Room

The present-day trend toward the family room as the living center of the home was responsible for this rejuvenation—the remodeling and lighting of an unfinished, concrete-floor basement in a 20-year-old home. Fortunately, the lighting consultant was called before remodeling began and the choice of sandalwood-finished wall panels with 50 per cent RF, light-colored ceiling, floor and furniture was due, in large measure, to her emphasis on the important contributions of these factors to the quality of the lighting installation.

Focal point of the recreation room (and location of the most interesting lighting element) is the arrangement of photographs along a wall at the foot of the basement stairs. To display the prints to best advantage, the consultant recommended a long line of wall lighting in the form of two 30-watt and two 40-watt fluorescent lamps mounted in a continuous row on the ceiling and shielded by a 7½-inch deep cornice board. The cornice is mounted 12 inches from the wall to provide a complementary wash of light not only for the photographs, but for the wall panelling below. With the addition of two recessed units on either side of the stairway, there are 19 footcandles of general illumination in this area, with 30 footcandles on the photographs. More important than the lighting intensity, however, is the even distribution of light over the entire wall and the absence of annoying reflections (no glass covers the photographs).

Another cornice in the far end of the recreation room is used as both an architectural and lighting device. Extending the full width of two adjacent walls, it creates a wide drop soffit ceiling which conceals the inevitable basement pipes. The lighting, limited to the length of the sofa, is from four 30-watt fluorescent lamps, butted end-to-end and mounted as far from the wall as possible, to give a smooth wash of wall lighting. Hand-fashioned, one-inch, wooden louvers shield the lamps from view. Beside the sofa, a portable floor lamp has been provided for reading light.

Cornice lighting dramatizes photographic display.

The other lighting elements in the room, while not unusual, add to the over-all comfort and decorative interest of the design. Over an extension table, a pull-down lamp on a ceiling track provides localized illumination for card playing or dining. An accent for the brick fireplace is obtained from an adjustable two-unit luminaire mounted 38 inches from the fireplace wall.

For downlighting in the center of the room (not shown) three pierced metal fixtures concealing 75-watt reflector floodlamps are mounted over the white-topped room divider, storage cabinet and serving counter to balance the generous amount of downlighting in other parts of the room. An added benefit is the light reflected from this matte white surface which creates a luminous background for the ping pong table. For direct lighting over the ping pong table, three recessed units with 150-watt lamps were installed, giving more than the recommended 30 fc for recreational table tennis.

Watson's Restaurant, Buffalo, N. Y.
Lighting designed by W. F. Guminski,
Niagara Mohawk Power Co.,
Buffalo, N. Y.
Western New York Section, Entry

Watson's Restaurant

Nothing can incite a businessman to action more quickly than a decrease in his business volume and at Watson's restaurant, a 30-year old establishment suffering from the competition of its newer neighbors, there was clearly a need for action. The restaurant was plagued by its dated décor and by the "black box" effect, a low level of general illumination and a few poorly lighted vertical surfaces which caused potential customers to wonder whether or not the restaurant was open.

Watson's original lighting installation consisted of 16-inch wide coves running the length of two side walls and similarly constructed coves on the center pillars. The coves were designed to use incandescent lamps, but with the passage of time and increasing laxity in maintenance, burned-out lamps were replaced with fluorescent lamps in various shades of white, with an occasional incandescent lamp still in use. A cove at the rear of the restaurant extending approximately three feet from the rear wall used four round frosted glass panels in an attempt to provide a downward component of light. Finally, a row of single-lamp fluorescent channels with frosted glass diffusers, mounted four feet from the floor in a recess in a center room divider, created an unavoidable source of direct glare. In its entirety, this was a poor "undesigned" lighting system which nullified the extensive redecoration of the restaurant.

Redesign of the lighting began with the elimination of the heavy side coves and all old lighting equipment. The new system was planned to give a comfortable level of general illumination, proper color rendition for food and complexions, sparkling highlights on silver and glassware.

To satisfy these conditions an enclosed recessed luminaire with Alzak aluminum parabolic reflector, Fresnel lens and A-19 clear 75-watt lamp was selected for general lighting. Three rows of these luminaires were installed on seven-foot lengthwise and nine-foot widthwise centers, with two units mounted over the food preparation area and one over the cashier's counter.

To eliminate the "black box" effect of the old lighting, a 32-foot cornice was built on each of the side walls and a 28-foot cornice on the back wall. These were equipped with a single-lamp fluorescent channels, mounted on the ceiling, eight inches from the wall, with ends butted. The eight-inch wide cornice boards, covered with the ceiling tile, inconspicuously create a vertical wash of light on the restaurant walls.

In addition to creating visual appeal with vertical illumination, the cornices serve several functional purposes. One side-wall cornice lights the counter equipment and menus on the wall; the rear-wall cornice accents a decorative clock. Light from the other side-wall cornice, in combination with 32 feet of wainscote lighting, displays a wall mural. On the side walls in the rear of the restaurant additional wainscote lighting, mounted four feet from the floor and using single-lamp fluorescent channels, increases the general level of illumination. Clip-on louvers have been installed where necessary.

As a decorative accent in the lighting scheme, ornamental chandeliers with six 25-watt inside frosted lamps in inverted cones of brass and opal glass were suspended 24 inches from the ceiling. These units, installed in two rows, three chandeliers per row, contribute an appealing sparkle on the glassware, china and silver.

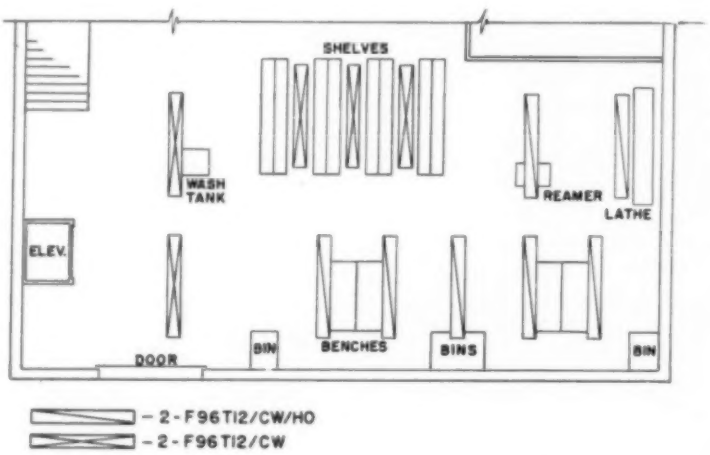
Final components in the new lighting are the surface reflectances—ceiling, 80 per cent; walls, 60 per cent (average); floor, 65 per cent; serving counter and tables, 75 per cent. The owner's verdict on the new lighting—an 11 per cent increase in business for the first five months following the remodeling and relighting.

Electric Motor Repair Shop

The quarters now occupied by this electric motor repair shop were formerly an old, unlighted warehouse. Conversion of the warehouse for the use of the present occupants involved refurbishing from the ground up—new floor, walls and ceiling painted and, of course, a lighting system to provide good seeing conditions for difficult tasks with a uniform high level of illumination unmarred by excessive contrasts or objectionable glare.

Surface remodeling, as recommended by the lighting engineer, included: natural wood floor, 30 per cent RF; flat white ceiling, 80 per cent RF; white upper walls, 80 per cent RF; light gray dado, 50 per cent RF. Lighting is from seven industrial luminaires, each with two 96-inch T12 cool white high-output lamps, 30-degree crosswise and 20-degree endwise shielding, and five industrial units each with two 96-inch T12 cool white slimline lamps and 13-degree crosswise shielding. Both luminaires have 25 per cent upward component. Mounting is at nine feet five inches on approximately five-foot centers, as shown in the plan view. Average illumination level in the work area is 100 footcandles, with 30 footcandles in the storage bin area.

Biedler's Electric Motor Repair,
Martinsburg, W. Va.
Lighting designed by
O. H. Lashley, Jr.,
The Potomac Edison Co.,
Hagerstown, Md.
Maryland Section, Entry



New Parameters for High Frequency Lighting Systems

By JOHN H. CAMPBELL

This paper is intended as a progress report for the planners of fluorescent lighting installations who in the near future may have the necessary equipment to provide the lighting advantages illustrated by recent laboratory developments.

LAMP CHARACTERISTIC data obtained over the past 12 years have clearly shown that fluorescent lamp characteristics improve with increased frequency to at least 20,000 cycles.[1,2] Factors such as higher lamp and system efficiency, as well as smaller and lighter weight ballasts, provide over-all advantages which have resulted in a number of outstanding high-frequency installations in recent years.[3,4] The power supply has been limited by economies and availability of frequencies under 1000 cycles. However, even at the comparatively low frequency of 420 cycles, the over-all cost of light is generally lower than the 60-cycle system for industrial and commercial applications of 50 kilowatts or more.

With the introduction of semiconductors capable of switching several amperes at high repetition rates, there may be the opportunity to provide fluorescent lamps with a-c power in the range of 1000 to 10,000 cycles and possibly higher. The feasibility of generating higher frequencies for fluorescent lighting has opened up additional investigations in the development of lamps and systems. A new set of parameters involving power supplies, ballast designs, and lamp characteristics has expanded possibilities for the future.

Lamp Characteristics at High Frequency

Although lamp characteristics at frequencies to 20,000 cycles have been investigated and reported, most of the system development work has been concentrated at the low frequencies for which power supplies are readily available. With the development of circuits and components for efficiently converting 60 cycles to much higher frequencies, lamp behavior at higher frequencies may be inspected with more than an academic interest.

In the tests to be described, all lamps were photometered for lumen output at 40 lamp watts. Therefore, the percentage gain in lumens with increasing frequency also represents an equal percentage gain in lumens per watt.

The recent rise in lumen output and efficiency of 40-watt lamps with 60-cycle operation is further increased at higher frequencies. Fig. 1 illustrates this characteristic. Although a short time ago 2800 lumens in a 40-watt lamp rating seemed difficult to obtain, changes in phosphors, filling gas mixture and pressure, along with the use of large anodes, has increased light output to a point above 3000 lumens. The same lamps operated at higher frequencies produced the percentage increases shown in Fig. 1. A 3100-lumen 40-watt lamp at 60 cycles would have ratings of 3300, 3350, 3450, and 3530 lumens for 1000, 3000, 10,000 and 20,000 cycles, respectively. At 60 cycles the lumens per watt are 77, but increase to 82, 84, 86, and 88, respectively, at corresponding higher frequencies.

All of the data illustrated in the form of curves or graphs were obtained while maintaining the input energy of the lamps at 40 watts. From previous tests it appears that the percentage increase in lumens and lumens per watt is essentially the same at considerably higher lamp watts.

It has been known for some time that a decrease in filling gas pressure of a pure gas such as argon will result in a slightly higher lamp efficiency at 60 cycles.

In order to examine the effect of low pressure, a quantity of 40-watt lamps was made with filling gas pressure of 1.0 mm of argon along with another group of lamps containing krypton at 0.5-mm pressure. In all other respects the lamps were of conventional design. Of the pure noble gases, these two were found to be optimum by a selective test for lamp efficiency gains in the pressures indicated. Conventional lamps filled to 3 mm of argon were used as a control lot for comparison. Fig. 2 shows the results of this test. All points were plotted with the 60-cycle value of the lamp containing

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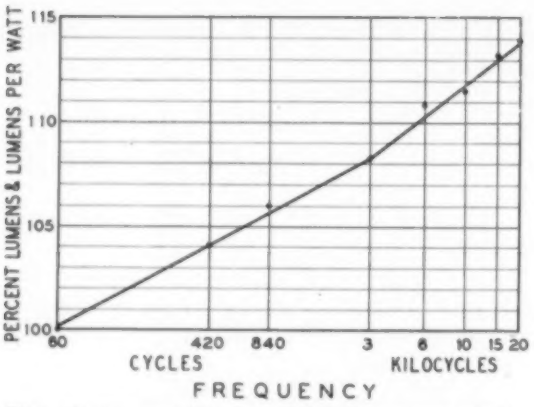

Figure 1. Per cent lumens and lumens per watt with increase in power frequency. Curve represents average of ten 40-watt T12 higher-lumen-output lamps. Lamp watts were held constant at 40 watts over entire frequency range.

3.0 mm of argon as 100 per cent. This illustrates an advantage for the argon-neon higher-lumen-output lamps at any frequency over conventional 40-watt lamps containing a single gas at optimum filling gas pressure.

All of the low pressure lamps of T12 bulb diameter exhibit an abrupt rise in efficiency between 400 and 840 cycles. In each instance the lamp voltage, which had been decreasing over the range of 60 to 840 cycles, starts to rise with increased frequency indicating a change in the positive column. The point in frequency at which this break occurs will vary, depending upon the diameter of the lamp.

End Loss

The end losses in fluorescent lamps consist of anode and cathode voltage drops along with the I^2R loss at the electrodes.[5] The latter will vary somewhat during the life of the lamp due to the change in position of the cathode hot spot as emission material is dissipated. Energy loss resulting from voltage drops at the electrodes is constant for equal current and the same bulb diameter regardless of lamp length. This fact provided the stimulus for determination of the end losses statistically. Groups of ten lamps each were made up in T12 diameter bulbs, but in several lengths from 24 inches to 96 inches. All lamps contained the same type of mount structure, electrodes, and filling gas. The lamps were measured for electrical characteristics at a constant current and the differences in average lamp watts for differences in lamp length were recorded to obtain positive column watts per foot of bulb. The product of this figure and the arc length in feet is the actual positive column watts. Subtracting this figure from total lamp watts gives the approximate end loss in watts. An example of this calculation is as follows:

$$X = W8\text{-}Y\frac{(W8\text{-}W2)}{(6)}$$

where X = Lamp end loss in watts
Y = Arc length in feet
W8 and W2 are the average measured lamp watts for 96-inch T12 and 24-inch T12 lamps.

Substituting:

$$X = 73.9\text{-}7.54\ \frac{(73.9\text{-}23)}{(6)}$$

$$X = 73.9\text{-}63.9$$

$$X = 10.0 \text{ watts}$$

Applying this method to the group of conventional T12 diameter lamps at two current levels resulted in the values given in Table I showing the end losses in watts for 425-ma and 800-ma operation and the theoretical per cent lamp efficiency if these losses were completely eliminated.

Since the end loss becomes a progressively smaller percentage of the total lamp watts with increasing arc length, the total gain in efficiency is also proportionately lower.

TABLE I—End Loss of Various T12 Lamps at 60 Cycles For High and Low Current Loading—Per Cent Efficiency with Elimination of End Losses.

	Total Lamp Watts		End Loss in Watts		Per Cent Efficiency Without End Loss	
Lamp Type	425 ma	800 ma	425 ma	800 ma	425 ma	800 ma
24T12	23	31	10.0	12.1	177	164
48T12	38	58	10.0	12.1	136	126
72T12	56	83	10.0	12.1	122	117
96T12	74	105	10.0	12.1	116	113

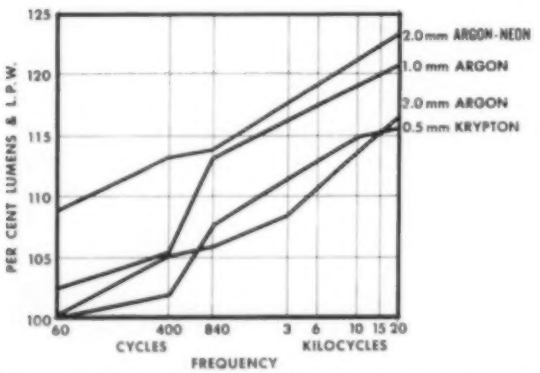

Figure 2. Per cent lumens and lumens per watt, 40-watt T12 lamps with filling gas pressures of 1.0 mm argon, 3.0 mm argon, 0.5 mm krypton and 2.0 mm argon-neon. Lamp with 3.0 mm argon at 60 cycles equals 100 per cent.

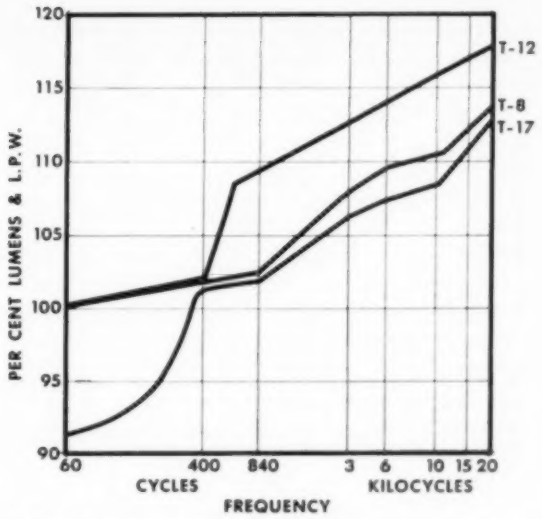

Figure 3. Per cent lumens and lumens per watt, T8-, T12- and T17-diameter 40-watt lamps. Filling gas pressure equals 1.0 mm argon. Forty-watt T12 lamp 60-cycle values equal 100 per cent.

Bulb Diameter

In addition to the T12 diameter, 40-watt lamps of the same length were made in T8 and T17 bulbs with a filling gas pressure of 1.0 mm of argon to determine the effect of bulb diameter on lamp efficiency over a wide frequency range. Fig. 3 shows the results of this test and indicates preference for T12 diameter bulbs at almost all frequencies except 400 cycles, where there is little difference. Fig. 4a is a graph showing per cent lumens and lumens per watt plotted at several frequencies and with T8, T12, and T17 diameter 40-watt lamps all filled to 1.0 mm of argon. Fig. 4b is a similar graph, but with all lamps filled to 3.0 mm of argon. These data emphasize the choice of T12 bulbs for 40-watt lamps and low filling gas pressure for maximum lumen output and efficiency regardless of frequency above 60 cycles. The effect of a change of bulb diameter at high frequencies with various combinations of filling gas mixtures and non-circular bulb cross sections is yet to be determined.

Electrical Characteristics

It has been well-established that lamp voltage decreases and lamp current rises with increased frequency. When lamp watts are maintained through the frequency range, the voltage drops faster than current increases until lamp power factor reaches unity (at 60 cycles the average lamp power factor is 90 per cent). The point in frequency at which the power factor becomes unity will vary depending upon lamp diameter, filling gas pressure, loading, and type of ballast circuit. The lower lamp voltage in part is due to lower cathode and anode drops, but positive column voltage also decreases. Lamp current must therefore increase to maintain lamp watts.

Figs. 5, 6, and 7 illustrate the change in lamp current and volts as lumens and lumens per watt increase with lamp watts held constant over the range of 60 to 20,000 cycles. The differences in the rate of change in electrical characteristics between curves of Figs. 5 and 6 are due entirely to the differences in argon filling gas pressure, while differences shown by the curves of Fig. 7 are due to the argon-neon filling gas mixture at a pressure of 2 mm. The significance of this information is the fact that with all the changes in lamp characteristics, lamp voltage drops to approximately the same percentage at 840 cycles in each of the three cases and then rises in the range of 840 to 3000 cycles. This is also coincident with the reduction in end losses which, from a separate test, reached

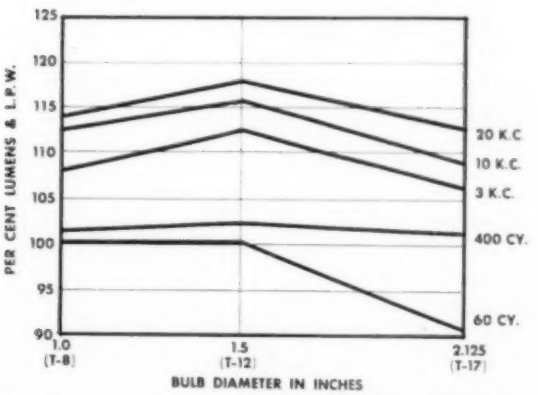

Figure 4a. Forty-watt lamps of T8, T12 and T17 diameters. Lumen output and lumens per watt at various frequencies in per cent of the 40-watt T12 value at 60 cycles. (Filling gas 1.0 mm of argon.)

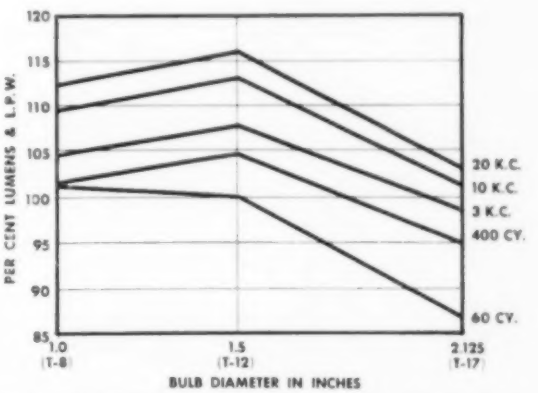

Figure 4b. Forty-watt lamps of T8, T12 and T17 diameters. Lumen output and lumens per watt at various frequencies in per cent of the 40-watt T12 value at 60 cycles. (Filling gas 3.0 mm of argon.)

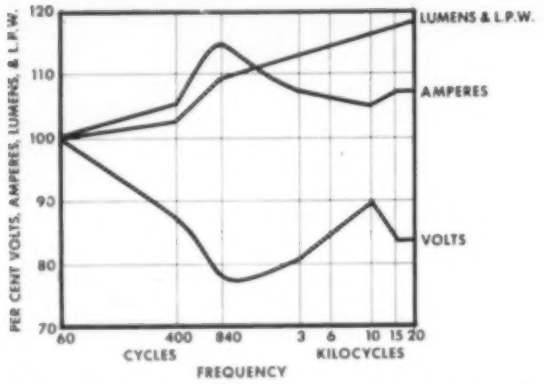

Figure 5. Per cent lamp volts, amperes, lumens and lumens per watt, 40-watt T12 diameter lamp. Sixty-cycle values equal 100 per cent. Filling gas pressure equals 1.0 mm argon.

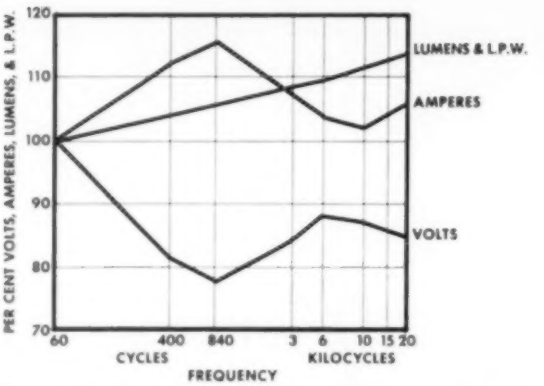

Figure 7. Per cent lamp volts, amperes, lumens and lumens per watt, 40-watt T12 diameter lamp. Sixty-cycle values equal 100 per cent. Higher-lumen-output lamp—filling gas pressure 2.0 mm argon-neon.

nearly the minimum at 840 cycles. Therefore, beyond 840 cycles, it can be assumed that most of the additional increase in lamp lumens and lumens per watt is due to an increase in positive column efficiency. The mechanism by which this takes place is not clearly defined. However, visual observations by the author in early tests indicated that the arc expands as frequency increases, thus conceivably producing 2537 radiation at a point closer to the phosphor. Dr. Carl Kenty has recently made d-c probe measurements between pairs of opposing probes near the center and at the wall of the bulb which also indicate an expansion of the discharge at high frequencies. The same is again indicated by visual observation. The larger ion currents to the walls, due to such spreading and shown directly by the probes, would result in higher arc gradients, higher electron temperatures, and therefore higher efficiencies in the production of 2537, while the production of 2537 closer to the wall as a result of such spreading provides better utilization of the 2537 production; on both counts the efficiencies should be increased. The spreading is believed to be caused in some way by the rapidly changing polarity of the arc at high frequencies; in any case, it could not be due to the skin effect as normally calculated for solid conductors.

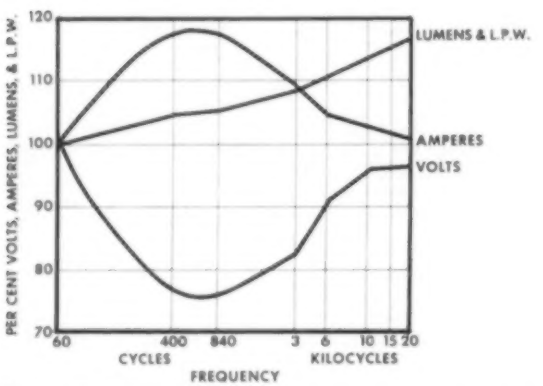

Figure 6. Per cent lamp volts, amperes, lumens and lumens per watt, 40-watt T12 diameter lamp. Sixty-cycle values equal 100 per cent. Filling gas pressure equals 3.0 mm argon.

Frequency

The optimum frequency will depend largely upon the location of the power supply. With present knowledge of the art, it appears that high frequency power systems may take three forms to cover various sizes of installations, with suggested maximum frequencies as follow:

(a) An Integral Power Supply (10,000 cycles),

(b) A Branch Circuit Power Supply (3000 cycles),

(c) A Central Power Supply (1000 cycles).

The integral power supply (Fig. 8a) of one to five kilowatts capacity would be located at a point

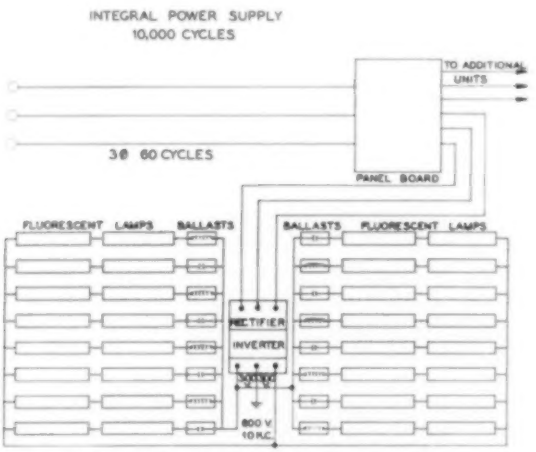

Figure 8a. An integral power supply.

near a group of fixtures or spaced to be in the center of a luminous ceiling. Due to the short distance from power supply to load, an output frequency as high as 10,000 cycles could be employed without excessive losses in the wiring.

The branch circuit supply (Fig. 8b) might be located in a panel box in the hallway. Power supplies at branch lighting circuits could provide up to ten kilowatts each at 3000 cycles. This allows for a derating factor of 12 per cent to permit distribution of 3000 cycles on 60-cycle wiring.[6] In some installations using branch circuit inverters, it will be lower in cost to rectify the 60-cycle power at a common point and distribute d-c to each branch circuit unit. The three types of ballast circuits are included in Fig. 8b to illustrate the freedom of choice in lamp and installation requirements.

A central power supply (Fig. 8c) could be located at the load center distribution point in an industrial plant, in the main transformer vault supplying a large commercial area, or in a cabinet on each floor of a large office building. In view of the comparatively high current and long lines from the supply to the load, the maximum frequency may be limited to 1000 cycles. However, the overall cost per kilowatt of installations involving several hundred kilowatts of lighting should be lower with a central supply. This block of high-frequency power may be made up of a number of inverters or a single inverter depending upon the current switching capacity of controlled rectifiers or power transistors. Controlled rectifiers capable of providing 100 kilowatts of high-frequency power may be available within the next few years.

Is There an Optimum Frequency?

From the standpoint of fluorescent lamp operation, the highest frequency capable of being produced economically is best.[7] However, there are many limitations necessarily imposed on the system designer, such as the switching capabilities of power transistors and controlled rectifiers, economical considerations in power distribution and controls exercised by the Federal Communications Commission on frequencies above ten kilocycles.

It is quite natural that considerable thought has been given to the possible standardization of a single high frequency for fluorescent lighting. If complete standardization is to be accomplished, it will require continued efforts on the part of design and application engineers in the semiconductor, ballast and power distribution fields. Meanwhile, the judicious selection of an optimum frequency for each of the three types of power supplies to cover various installation conditions will provide maximum flexibility of design and permit the use of any presently available lamp type.

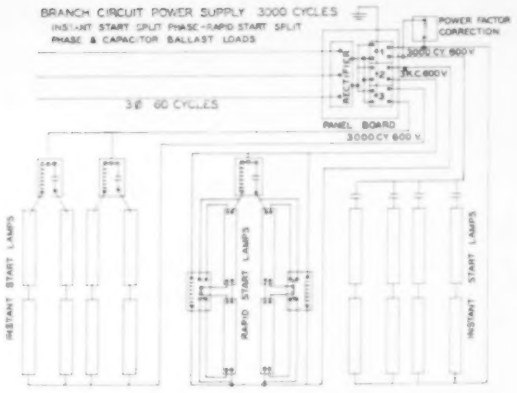
BRANCH CIRCUIT POWER SUPPLY 3000 CYCLES
INSTANT START SPLIT PHASE-RAPID START SPLIT PHASE & CAPACITOR BALLAST LOADS
POWER FACTOR CORRECTION
3000 CY 600 V
D.C. 600 V
3Ø 60 CYCLES
PANEL BOARD 3000 CY 600 V.
INSTANT START LAMPS
RAPID START LAMPS
INSTANT START LAMPS

Figure 8b. A branch circuit power supply.

Voltage Distribution

The highest permissible voltage for distribution to lighting loads in commercial or industrial installations is 600 volts line-to-line and 300 volts to ground. This is accomplished in 400-cycle systems by designing the three generator coils for 600 volts and center tapping each of the coils to a common ground.[3]

Semiconductor inverters generally require a transformer in the output circuit, making it even more convenient to supply maximum voltage with a center tap to ground. The high voltage to the load provides adequate starting voltage for any instant-start lamp up to 96 inches in length and any rapid-start lamp for two in series ballasts. In addition, the 600 volts represents a considerable savings in wiring cost from the inverter to the load where branch circuit or central power supplies are considered. A length of cable can deliver up to three times as much power at 600 volts as it can at 208 volts.[4]

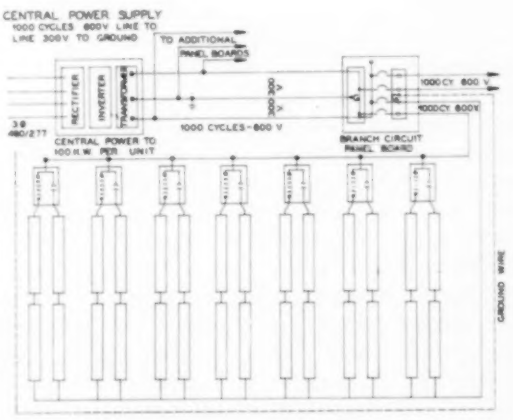

Figure 8c. A central power supply.

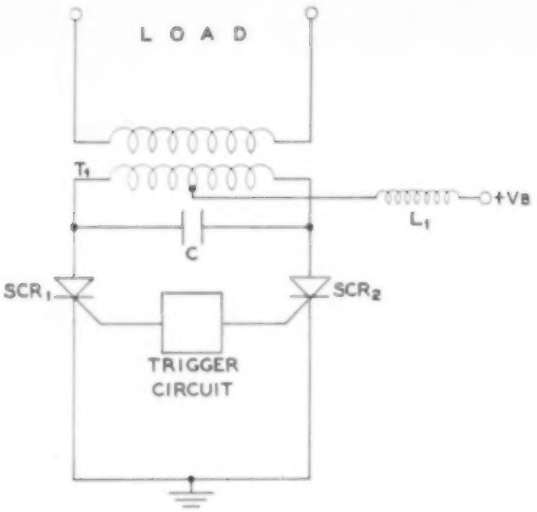

Figure 9. Basic parallel inverter circuit with silicon-controlled rectifiers.

Semiconductor Inverters

In the process of developing advance versions of high-frequency lighting systems, a number of basic inverter circuits using power transistors and controlled rectifiers were investigated. In all of the experimental designs, the circuits and associated components were modified to meet the complex requirements of the fluorescent loads. The scope of this paper does not permit a detailed account of this work, but the material could well be the subject of a subsequent technical paper in the near future.

Fig. 9 illustrates a basic silicon-controlled rectifier, parallel inverter circuit. The controlled rectifier is designed to have characteristics similar to those of a gas thyratron, but the forward drop is only one-tenth that of a thyratron and the deionization time is considerably less. The short deionization time permits the device to be turned on and off at a higher rate than would a thyratron tube, and the lower drop allows the device to pass a high current with less loss. These characteristics coupled with the elimination of a filament transformer permit a design for high-frequency output at very high efficiency. Basically the inverter operates as follows:[8] the trigger circuit is designed to apply pulses alternately to the gates of SCR_1 and SCR_2. Assuming that SCR_1 is conducting and SCR_2 is blocking, the current from the supply V_B will then flow through the left-hand side of the transformer T_1. This transformer action will produce a voltage of approximately $2V_B$ at the anode of SCR_2 and across capacitor C. When the next trigger pulse is applied to the gate of SCR_2, it will turn on and the voltage at the anode of SCR_2 will fall to a value equal to the forward conducting drop. The voltage at the anode of SCR_1 will fall to approximately $-2V_B$ because of the action of the commutating capacitor C. The capacitor C will maintain a reverse bias across SCR_1 long enough for SCR_1 to recover to the blocking state. The next trigger pulse will occur at the gate of SCR_1 and cause the circuit to revert to the original state. In this manner, the current from the supply V_B will flow alternately through the two sides of the transformer primary and produce an a-c voltage of a frequency corresponding to the rate at which pulses are applied by the trigger circuit.

Over-all Efficiency

It is expected that the over-all efficiency from the input terminals of the inverter to the input terminals of the lamp will be in excess of 90 per cent at any output frequency within the capabilities of the semiconductor. With the increase in lamp efficiency it is possible to provide a higher over-all efficiency, including all the losses in the system, than our present 60-cycle lamp efficiency alone. An example is the argon-neon 40T12 higher-lumen type lamp which has a 60-cycle lamp efficiency of 77 lumens per watt and an over-all efficiency of 64 lumens per watt. At a frequency of 10,000 cycles, these figures become 86 and 78, an increase of 21 per cent in over-all efficiency. No attempt will be made here to compare the over-all cost of light at various frequencies since semiconductors of the size needed for general lighting have not as yet reached a competitive cost with rotating equipment, and their reliability in lighting inverters has not been established. However, it may suffice to repeat that costs projected to a point within the next few years justify optimism, and the over-all efficiency increase will count heavily in the final cost comparison.

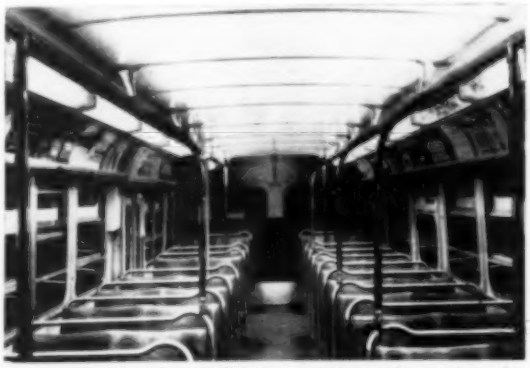

Figure 10. Bus equipped with experimental transistor inverter providing 3000 cycles for 42T6 slimline lamps. The 16 lamps are operated on eight two-lamp ballasts weighing only three-quarters of a pound each. Lighting levels range from 25 to 35 fc. By contrast the filament lighting system measured from 4 to 12 fc.

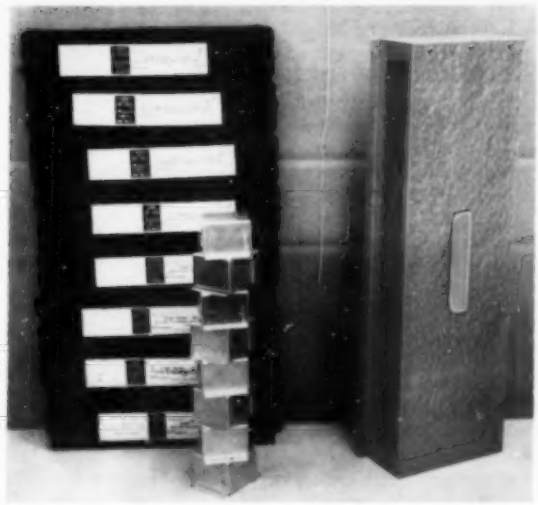

Figure 11. Twenty-pound transistor inverter is shown at right. In left foreground are eight two-lamp 3000-cycle ballasts stacked next to the same number of 60-cycle two-lamp ballasts. Sixty-cycle inverter (not shown) would be required if bus had been equipped with conventional ballasts (left background).

Semiconductor Power Supplies for F-Lamps

In the process of investigating the new possibilities of the high-frequency lighting systems, a power transistor inverter was developed by H. E. Schultz, an associate of the author. This prototype power supply has been in operation since April, 1959 in a Cleveland Transit System Bus (Fig. 10). In addition to providing over three times the lighting level of filament lighted buses, this unit is being tested to determine transistor and other component reliability for possible use in general lighting. An over-all efficiency of 88 per cent is obtained in supplying power to 16 42-inch T6 slimline lamps. Fig. 11 shows the 3000-cycle power supply and ballasts compared to the conventional 60-cycle ballasts normally used for the 42-inch T6 lamp in other applications.

Controlled rectifiers and power transistors are becoming available at higher voltages, and circuits similar to that of the bus inverter, but rated at several kilowatts and higher efficiency, are being tested for use in general lighting.

Circuits

When power supplies are designed for frequencies in the range of 1000 to 10,000 cycles, it does not appear that ballast circuits will change appreciably over circuits described in previous papers for 360, 400 and 840 cycles.[9] Most semiconductor inverters operate best when connected to a unity power factor load. At high frequency this is easily accomplished by designing each two- or four-lamp ballast with the familiar split-phase circuit in which one or two lamps are operated from a series choke and a corresponding number from a series capacitor. If starting voltage is distributed from the inverter, instant-start ballasts will not require a transformer. Rapid-start ballasts will need only the preheat transformer in addition to the series elements.

If the lamp load for each inverter is to be switched so the load is completely on or off, each lamp or pair of lamps in series can be operated from a single capacitor ballast with a central choke connected across the inverter terminals to compensate for the leading current and to provide unity power factor.[1-6] This simplifies the ballasting, but the lines leading to the load will be conducting a higher current and will require larger wire size than the split-phase ballast system.

Conclusions

The increasing demand for higher levels of illumination has been stimulated by the development of high-lumen-output lamps and systems. This in turn has created a greater need for a fluorescent lighting system with maximum efficiency for the higher wattage loads and maximum flexibility to accept the still higher lumen-output lamp designs which are certain to follow. High-frequency power systems appear to qualify for this role. In addition to extending the proved advantages of 360-, 420- and 840-cycle systems, the use of semiconductors provides a considerably greater over-all efficiency in the range of 1000 to 10,000 cycles. While the higher frequency system is as yet in the experimental stage, it has challenged the ingenuity of product designers and is currently receiving a great deal of attention.

Acknowledgments

The author wishes to acknowledge the considerable contribution by Harry E. Schultz to high-frequency lighting systems in the development of semiconductor circuits for inverters, one of which is the power supply for bus lighting reported in this article. Acknowledgments are also due to Dr. Carl Kenty for his assistance and advice with regard to the positive column phenomena and to Messrs. G. E. Inman and V. C. Kauffman whose continued support of this project made this paper possible.

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DISCUSSION

G. C. HARVEY:* The data and information Mr. Campbell has presented is a valuable addition to the fluorescent lighting art. Certainly the influence of an increase in lamp efficiency of the order of ten per cent will help to offset a possible higher first cost that may result at first with a system using semiconductors.

The data presented, while limited to one lamp rating, indicate a positive gain in efficiency at higher frequencies when compared to normal 60-cycle operation. I would appreciate some comment by the author as to whether he feels this gain is a natural one or whether his observations lead him to believe that lamp designs can be further optimized at 60 cycles, so that the reported improvement at higher frequencies would be reduced.

In suggesting certain maximum frequencies, depending on application of the frequency inverter, I assume the author has thought primarily of the influence of line losses. I presume he is also interested in suggesting some frequency level that would tend to standardize such applications. Although it will be very worth while to standardize frequency levels, many factors in addition to line losses are important. For example, audible noise, interference, adaptability to other equipment, lumen maintenance and lamp life would be good subjects for discussion.

Does the statement that 96-inch instant-start lamps will start on 600 volts indicate that these lamps will start more readily at high frequency or that the 60-cycle requirement of about 625 volts nominal may be higher than necessary?

In addition to the fact that a transistorized inverter is in successful operation, lighting the interior of a transit bus, I am aware of the work and plans of the author to develop a power supply which can be applied to general interior lighting. As it is extremely important to obtain component reliability experience and as most lighting engineers will be interested in this work, it would be appreciated if Mr. Campbell would outline his plans regarding such a developmental field installation.

C. L. AMICK:** With the 1958 adoption by IES of recommended illumination levels some two to three times those previously employed, it is appropriate that Mr. Campbell should bring our members up to date on higher frequency operation of fluorescent lamps to achieve efficiency gains which will lower the unit cost of light. Improvements in lamps and operating equipment, which give the owner more light for his money, will certainly speed the acceptance of our new footcandle recommendations.

The author has suggested three locations of the conversion equipment, providing power at frequencies of 1000 cycles and higher, which his conclusion classifies as being "in the experimental stage." Would he comment on the probable availability of small or transistor inverter units designed for 120- and 277-volt a-c systems, and perhaps similar in size to those employed on the Cleveland Transit System bus which powers sixteen 42-inch T6 slimline lamps? How about still smaller transistor converters to be located in the wireway of each fixture? I presume that present economies are unfavorable for the latter, but from the standpoint of the lighting specifier, contractor and owner, the simplest high-frequency system would be a small, maintenance free converter in each fixture.

While semiconductor inverters are being perfected for fluorescent lighting systems operating at 1000 to 10,000 cycles, there will continue to be installations of 360-, 420- and 840-cycle systems. It would be of real help if Mr. Campbell could make available the details of his cost comparisons. This could well result in consideration of high-frequency systems for commercial and industrial lighting loads less than 50 kilowatts, if power rates or hours usage per year are above average. Perhaps in addition to details of his economic study, the author could provide "break-even" curves showing what combinations of lighting load, cents per kilowatt hour, and hours' operation per year would favor each of the present conversion systems over conventional 60-cycle operation.

GEORGE A. MEYERS:* This paper very adequately summarizes the performance characteristics of lamps with ten watts per foot loadings and the potentialities of the semiconductor power supplies with which they may be operated.

In Fig. 2, higher-lumen type lamps are shown to have a nine per cent advantage over regular lamps at 60 cycles. This advantage appears to decrease with frequency, which suggests that these lamps should not be used in high-frequency systems. Was a sine wave power supply used in the tests from which the lamp data in Figs. 1 to 7 were derived?

The savings in ballast weight and losses with high-frequency operation of high-output and extra-high-output lamp types are even more pronounced than is the case for lamps of lower loading. Does the author's use of 40-watt data only (ten watts/foot loading) represent a conviction that this is the best system at the present time?

I share the author's optimism regarding the potentials of semi-conductor type power supplies and I would like to ask him what he considers to be the major problems currently associated with this type of equipment.

It seems to me that the field of high-frequency lighting will not get any real impetus until some degree of frequency standardization is agreed upon so that package deals will not be necessary, thus enabling all equipment manufacturers to share in its promotion and progress.

DOMINA EBERLE SPENCER:** Mr. Campbell has continued the tradition of outstanding work established in his earlier papers on high-frequency lighting. Of particular importance are three statements:

(a) For all combinations of fill gas, length, and diameter

*General Electric Co., Danville, Ill.
**Day-Brite Lighting, Inc., St. Louis, Mo.

*Sylvania Electric Products Inc., Danvers, Mass.
**University of Connecticut, Storrs, Conn.

studied, there is steady improvement in lamp characteristics over the range from 60 to 20,000 hertz.[1] At 20,000 hertz, the slope of the curves is still positive. Thus, as far as the fluorescent lamp is concerned, the higher the frequency the better.

(b) The optimum practical distribution voltage is 600 volts.

(c) Semiconductor inverter circuits may provide power in the range of 1000 to 100,000 hertz and possibly at higher frequencies.

Thus, there is the practical possibility of new and economical distribution systems at frequencies far above 60 hertz. Such systems are of great importance and further papers on their development are much to be desired. Among the many questions that occur on the semiconductor inverter circuits is the wave form of the voltage supply. Is the wave sinusoidal or of some other shape?

With Mr. Campbell, I look forward to the standardization of high-frequency power supplies at an optimum frequency. In lighting design our basic principle is to provide optimum conditions for human vision. In power supply design, we have a similar basic principle: to provide optimum conditions for lamp operation. A question is, for which lamp should we design? The requirements of incandescent lamps are satisfied by our present 60-hertz systems. Those of our fluorescent lamps are met by higher frequencies, perhaps from 3000 hertz to much higher values. Would it not be wise to also include the frequency characteristics of electroluminescent lamps in our thinking? Is there not a possibility that the benefits to be derived from high-frequency operation are even greater for electroluminescent than for fluorescent lamps? Both should be considered in determining the optimum frequency for tomorrow's power supplies.

One last question. The author has suggested maximum frequencies of 100, 300, and 10,000 hertz for control, branch-circuit, and integral power supplies respectively. Are not these apparent limitations based on the assumption that power is distributed on standard 60-cycle wiring systems? If distribution lines are compensated at suitable intervals, is it not possible to distribute any of the frequencies considered on transmission lines of any length?

J. H. CAMPBELL:* Mr. Harvey has presented several important questions related to lamp, inverter and ballast characteristics at high frequency.

The first question concerns the possible design of a lamp to provide the same efficiency at 60 cycles as we have obtained at higher frequencies. To date any change made in a lamp design to increase efficiency at 60 cycles has resulted in additional increases at higher frequencies. In view of the increase in positive column efficiency at high frequencies, it is more likely that the efficiency gap between 60 cycles and higher frequencies will widen rather than narrow.

Mr. Harvey suggests a discussion relating power frequency to audible noise, lumen maintenance and lamp life. Each of these factors deserves consideration. When tests now underway are completed, reports covering these and other phases of lamp and component characteristics will be available. The closer we approach the limit of human hearing sensitivity, the easier it will be to design quiet choke coils for ballasts. Since the frequency of the noise we hear from a ballast is double the fundamental power frequency, 9000 cycles may be optimum from the ballast design standpoint. Most of the conducted or radiated noise would then be at 18,000 cycles, which is above the normal hearing range. However, the Ferrite core materials can be used advantageously above 1500 cycles, and silent ballasts have been made of this material at a frequency of 3000 cycles. Tests in the range of 420 cycles have shown that the life and lumen maintenance is the same as 60 cycles when lamps are operated at equal watts. Further tests are being conducted to cover much higher frequencies.

Tests on a large number of 96T12 slimline lamps at 420 cycles and higher frequencies show reliable starting at voltage levels considerably under 600 volts. Possibly the 60-cycle tests should be repeated to determine whether a lower nominal voltage is now justified at that frequency.

Mr. Harvey asks that current plans for development of large power supplies for interior lighting be outlined. Component reliability tests are planned in connection with lamp life and lumen maintenance tests at several frequencies. A five-kilowatt power supply using silicon-controlled rectifiers is being prepared for a trial installation. A larger branch circuit supply is also being considered.

Mr. Amick raises some appropriate questions concerning the types of inverters being considered and the related economics of semiconductor inverters.

With regard to the availability of the various sizes of inverters rated at 120 and 277 volts, it may be in order to reiterate that the development work described in this paper is experimental and much more work must be done by the product designers before the inverters are ready for the market. This will probably take place in special lighting fields, such as bus lighting, with the larger supplies to follow as soon as system reliability and economics are favorable for these applications.

I agree that a small maintenance-free converter for each fixture would provide the simplest high-frequency system. Unfortunately, such a converter would not be small; since each power supply fed from a conventional 60-cycle single-phase distribution system would require a comparatively large filter choke in the rectifier, largely offsetting the advantage of the small, lightweight high-frequency ballast. Larger converters can be conveniently located near a source of three-phase power, permitting the use of bridge rectifiers without filters. As Mr. Amick anticipated, the economics of small transistor converters for individual fixtures would not compare favorably with a multifixture power supply. The use of semiconductors has not changed the fact that the cost per kilowatt decreases as the block of power increases.

His second question refers to the details of the cost analysis used in determining economic comparisons for 60-, 420- and 840-cycle systems. The scope of this paper did not permit the inclusion of this analysis, but complete information on this subject can be obtained from the references accompanying the paper.

Mr. Amick also asks for the "break-even" figures showing the points which would favor each of the present conversion systems over conventional 60-cycle operation. The "break-even" points will vary depending upon the choice of lamps, kilowatt capacity of the system, over-all efficiency, etc. This could well be the subject of another paper, but figures obtained from our application engineering studies indicate a range of $62/kw to $240/kw.

Mr. Meyers suggests that the 40-watt higher-lumen-output lamps gradually lose their advantage over conventional 40-watt types as frequency rises. The latter is represented by the 3-mm argon curve in Fig. 2. The advantage in efficiency drops only slightly (9 per cent to 8 per cent) from 60 cycles

[1] An internationally standardized unit of frequency equivalent to "cycles per second."

* Author.

to 10,000 cycles. Lamps with 1 mm of argon come within three percentage points of the higher-lumen-output lamp at 10,000 cycles, but these are experimental and are shown only to indicate possible gains with reduction of filling gas pressure alone.

With regard to waveform, all measurements were made with equipment providing a sine wave with very low distortion over the entire frequency range.

Mr. Meyers asks about the exclusive use of 40-watt lamps in all of the testing. This was done to keep the quantity of data within practical limits for analysis and presentation. Also, to test all lamp types for each variable will require years. However, spot checks on longer lamps for frequencies above 1000 cycles indicate significant gains in lamp efficiency. There are no convictions on the part of the author that 40-watt lamps provide better over-all performance on high frequency than the longer or higher wattage lamps. The preference for lamp types will no doubt depend upon application requirements and over-all economics regardless of frequency. Lamp characteristics with changes in frequency for a variety of standard sizes have been shown in previous papers (see references in paper).

Determination of the optimum frequency is certainly to be desired, but it need not be a prerequisite to the success of the system. Any fluorescent lamp can be operated at any of the frequencies being considered. It becomes an advantage, therefore, to select one of the three frequencies which best fits the location of the power supply or the application. This present flexible arrangement would, of course, become unnecessary with development of a power distribution system capable of delivering high frequencies at high current for several hundred feet with a net gain in over-all economy. It does not appear to me that a "package" deal (*i.e.* the need to sell totally engineered systems) would be any more likely with three frequencies than is the case today with transformers and ballasts designed to accommodate three voltages (120, 240 and 277).

In any new development program it is difficult to anticipate all of the problems associated with the complete system. However, with regard to semiconductor power supplies, we would be in a better position to design inverters for all conventional input voltages if these devices were now available with higher voltage ratings and with lower saturation resistance at high frequencies.

Dr. Spencer raises some questions which should stimulate thinking in terms of specific developments in high-frequency power distribution. The suggested locations of power supplies and corresponding frequencies were made considering the utilization of 60-cycle wiring. A comprehensive study of both technical and economic facets of high-frequency power distribution may lead to an optimum frequency for fluorescent lighting. However, at the present time semiconductors of high-current and high-voltage ratings needed for large central supplies are limited to frequencies considerably below the maximum of 10,000 cycles. Consequently, the derating to 1000 cycles for large central supplies was not a limitation of 60-cycle wiring alone. The low voltage, low current semiconductor converters capable of providing maximum frequencies can be located close to the lighting load and would, therefore, not require a special power distribution system.

I agree with Dr. Spencer that electroluminescent lamps should be considered along with fluorescent lamps in any effort to arrive at an optimum frequency for lighting. However, the load characteristics of the two light sources differ appreciably, which may necessitate separate designs of power supplies and distribution lines whether or not the frequency is the same.

Comparison of Visibility Measurement Systems

(Discussion of a paper by A. A. Eastman and S. K. Guth Published in March Illuminating Engineering)

J. M. WALDRAM:* The "measurement" of visibility has been a controversial subject for many years and the most recent work on it by Blackwell has, I fear, but increased the doubts which many have felt about the validity or even the possibility of such measurements.

The first and most fundamental point is that one cannot measure anything until one can define it. The term visibility is used with so many different meanings, and the act of discerning an object is carried out in so many different ways that a single arbitrary system of measurement can never be satisfactory. In various contexts we mean by visibility: how *easily* can it be seen; how *well* can it be seen; how *far* can it be seen; in what *detail* can it be seen; how *quickly* can it be seen; how *clearly* can it be seen; how *often* will it be seen and how *likely* is it to be seen? These considerations are quite apart from its specialized use in meteorology and physiological optics. A system of measurement adopted without formal definition amounts to a definition in itself, but its meaning is hidden; "visibility is what my instrument says it is." One is led unconsciously by such systems into statements like that by the authors: "It is a well-known fact that the unaided eye is an unreliable judge of the magnitude of the difference in visibility between two visual tasks." Whatever precise meaning we give to the term, visibility involves the idea of how well one can see something; and if the eye cannot appraise the difference, can there be any real difference? Or if the observer feels that two tasks are so different in kind that he cannot compare them, as being quite unlike things, are not our efforts to bring them to a common basis likely to be spurious?

Earlier papers have illustrated tasks which, according to some system of measurement, were rated as of equal visibility but which were so different in kind that one could not mentally equate them at all. One example was a child's handwriting in pencil, a little hard to read because the letters were badly formed as well as being of rather low contrast, which was equated to clear black and white print which was a little hard to read because it was small. The visual and mental mechanisms involved were altogether different in the two cases and it was not possible to regard them as at all equivalent. A more searching example is

*The General Electric Co. Ltd., Research Laboratories, Wembley, England.

Figure 1. Object fixated and perceived in detail by peripheral vision.

Figure 3. Object dropped on table among collection of similar objects. Parafoveal vision inadequate to distinguish it.

shown in Figs. 1-4. In Fig. 1 a small screw is being examined, held in forceps. It is seen in clear detail by foveal vision; fixation is easy and automatic because it is located by the forceps. In Fig. 2 the screw has been accidentally dropped onto the table and is about to be picked up. The operator has now only to discern the position of the screw, not its detail; he does not know where it is and locates it at first by peripheral or parafoveal vision at low detail, which leads him to fixate it if he wishes to. One does not attempt to see detail parafoveally; parafoveal vision is used to locate the object and it is fixated if we need to see detail. In Dr. Blackwell's work a factor of four is allowed in case one is looking away from the object, surely quite unnecessarily. However, in Fig. 3 the screw has landed not on the featureless table, but among a large number of rather similar objects, from which it has to be distinguished. Now peripheral vision is of little help, for the detail visible by it is insufficient to distinguish the screw from the other objects; one has to search until by chance one sees it by foveal vision (Fig. 4) and recognizes it in detail, sometimes after several false attempts. Increasing the illumination will not enable detail to be seen parafoveally. Yet the brightness pattern presented by the screw and its immediate background are exactly the same in all three cases; nevertheless the visual problem, the means by which it is solved and the time taken to solve it are very different. What is the "visibility" of the screw?

The formal methods, either Luckeish-Moss or Blackwell, operate by degrading the *contrast* of the object (or its brightness and contrast together) until it is just invisible, usually by foveal vision, finding some standard test object which is also just invisible under the same degradation, and assuming that therefore they were just equally visible before the degradation. This is, however, an unjustifiable assumption. It may mean trying to compare one object of which it is necessary only to discern the presence with another of which one must discern the detail or distinguish it in some way from a similar object. It also assumes that the further an object is from the disappearance condition, the more "visible" it is on a continuous scale. But neither is this necessarily true. For example, in the course of some experiments[1] on the visibility of road traffic signs, the contrast of the sign was degraded and it was found that little difference in the distance or ease with which the sign could be read occurred until the contrast was very much reduced. Thus for a wide range of contrasts the visibility

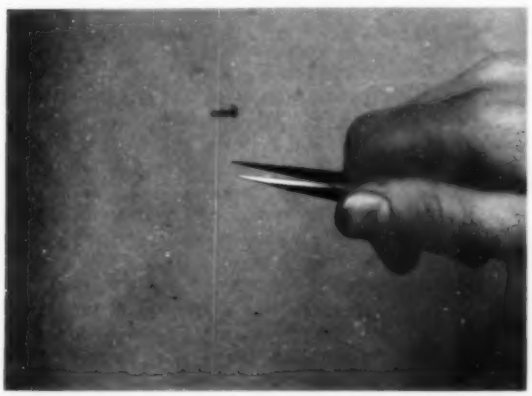

Figure 2. Object dropped on table: out of focus and away from fixation point. Found by parafoveal vision, at low detail and subsequently fixated.

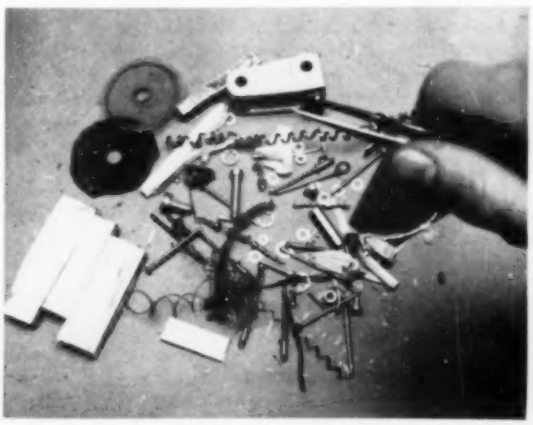

Figure 4. Situation as in Fig. 3. Observer has to fixate objects in turn before he can identify the screw.

did not change very much, so the distance from the threshold is a quite unreliable measure of it. The authors invoke the axiom that "things equal to the same thing are equal to one another." But that axiom does not apply to the methods in question. All that the methods do is to find things which are at the same distance, measured along an arbitrarily chosen photometric route, from a stated condition, not attained in every case in the same way. Things which are the same distance from a similar thing are not necessarily equivalent to one another.

Finally, the methods seek to establish an order of luminance, or illumination, which will bring the "visibility" of various objects to the same level, including even the speed with which they can be "assimilated." (I will not even comment upon the logic of the step whereby the threshold time of presentation becomes "assimilations per second.") Some things are difficult to see, and some are easy, for various reasons. If they are too small to be seen easily, the remedy is by some means to make them bigger, not necessarily to make them brighter. Certainly at higher levels the eye can see slightly smaller detail and so may see the smaller thing a little more easily if the ranges involved are convenient; but the conditions may easily arise in which no amount of increase of illumination can ever succeed in making the difficult thing as easy to see as the easy thing. It is like determining the relation of an athlete's performance to the food which he eats and deducing from that how much food *I* should require to run a four-minute mile.

1. Smyth, J. S.: *Transactions of the IES* (London), Vol. XII, p. 71 (1947).

A. A. Eastman and S. K. Guth:* We agree with Mr. Waldram that the term "visibility" has many different meanings, but we disagree with his opinion that it cannot be defined and measured. Our use of visibility and its measurement has been clearly set forth in the literature referred to in our paper. Dr. Blackwell has carefully explained his method of measuring visibility and its relationship to his visual performance data.

Visibility can be described qualitatively in many ways. However, it does seem highly desirable to be able to assess it on some quantitative basis. Any of the various contexts listed by Mr. Waldram can be used as a basis for evaluating visibility, but some lend themselves to meaningful measurement more readily than others.

In many respects, a visibility scale is no more arbitrary than many other systems of measurement in common use. All that is necessary is to specify or define the units being used. The distance between two geographical points may be measured in English miles, French kilometers, or a mountaineer's "whoops and hollers," but the distance remains the same regardless of the units of measurement! So, the contrast of a standard disc, the visual size of a parallel bar test object or the equivalent type size may be used to describe the visibility of a task without departing from accepted practice in measurement.

Mr. Waldram appears to have overlooked the word "magnitude" in referring to the statement, "It is a well-known fact that the unaided eye is an unreliable judge of the magnitude of the difference in visibility between two visual tasks." The eyes often can appraise qualitatively, but not quantitatively without instrumentation.

It seems to us that to call efforts to bring unlike objects to a common basis as "likely to be spurious" is in itself spurious. Even apples and oranges can be compared in terms of their ability to provide nourishment. It certainly is logical to assume that two objects which can be just barely seen in identical fractions of time, through identical densities of filters or at identical distances, are equal in visibility. The fact that the two tasks may differ considerably in contrast, brightness or size is immaterial. Two stars of the third magnitude are rated as equivalent even though one may be closer or larger than the other; this is a visibility rating in terms of apparent brightness. If such a concept is suitable for one purpose, it should be equally appropriate for others.

As for the visibility of the screw in the various surrounds, Mr. Waldram may have become somewhat confused by the complexity of the problem. A particular screw or any other object can have many ratings of visibility, depending upon the conditions of viewing. A visibility rating usually is a static evaluation with specific, described viewing conditions.

When the task involves locating a specific screw among many others, it includes a number of other perceptual factors, especially speed and accuracy. These are encompassed by what usually is called visual performance. Even in this case, measurements of visibility will be of considerable help in understanding the visual task and in determining its lighting requirements so that it can be seen as quickly as possible. How else can one determine whether an object can be seen during a momentary glance in its direction? Furthermore, by using the appropriate criterion —detection of presence or discrimination of detail—it is possible to evaluate the task in terms of the seeing requirements involved.

In common with many others, Mr. Waldram apparently concludes that measurements of visibility imply that equal changes in *relative* visibility as indicated by the calibration of an instrument correspond to equal changes in *subjective* visibility. As we have pointed out many times, this is not the case. That is, doubling the size or contrast of an object does not mean that it is twice as visible subjectively any more than increasing the photometric brightness of an area by a factor of two means that the subjective brightness is doubled. Furthermore, the fundamental data upon which measurements of visibility are based bear out the fact that many highly visible objects can be degraded appreciably in size or contrast without seriously impairing the viewing distance or time for seeing.

It is indeed true, as Mr. Waldram suggests, that no amount of illumination will raise the visibility of some extremely difficult tasks to the level of a less difficult task. But, isn't it important to find that out by measurement instead of just guessing? The "footcandles for equal visibility" are useful as a guide for classifying the relative difficulty of various visual tasks. This is important in today's world of measurements.

The sole purpose of our paper was to show how measurements made with the Luckeish-Moss Visibility Meter could be related to the Blackwell Visual Task Evaluator measurements. This we have done, including suggesting why some of the conversions are not perfect. We fully recognize that there are inherent limitations in any method of evaluating visibility. Nevertheless, visibility can be measured. Such measurements provide valuable information which can be obtained in no other way.

Bumblebees are still flying although calculations in aerodynamics once proved that they can't. Mr. Waldram may not be a potential "four-minute miler" but we wonder if he ever went swimming immediately after partaking of a very heavy meal. Diet may not make an athlete but it certainly can unmake him! Therefore, we will continue to measure visibility even though some feel that it "can't be done."

*Authors.

A.I.A. File No. 31*f*

INSTALLATION AT UNION ELECTRIC CO. SERVICE BUILDING,
18TH AND GRATIOT STS., ST. LOUIS, MO.

Lighting a Telephone Equipment Room

LIGHTING OBJECTIVE: To provide general lighting in a telephone equipment room for periodic rough inspection.

GENERAL INFORMATION: This type of location is usually unattended but is regularly maintained. Here the automatic dial telephone equipment is mounted in racks which form "corridors" 2½ feet wide as shown in the above illustration. Reflectances of the major surfaces are: ceiling, 65 per cent; walls, 59 per cent; floor, 18 per cent; and equipment covers, 50 per cent. Convenience outlets located on the walls provide the source for portable supplementary lighting when necessary.

INSTALLATION: Each of the "corridors" is lighted by a continuous row of surface-mounted Westinghouse catalog No. LC-80RP-30 louvered fluorescent units. Each unit is equipped with two 40-watt T-12 cool white fluorescent lamps. The average level of illumination on the floor was 56 footcandles. Brightnesses and illumination levels (vertical) on the telephone equipment housings were:

	fc	fL
upper quarter	72	34
upper middle quarter	31	15
lower middle quarter	20	8
lower quarter	16	7

Lighting data submitted by Carter Lewis and William H. Simms, Union Electric Company, St. Louis, Mo., as an illustration of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31*f*

Design Requirements for High Lumen Maintenance and Easy Starting of Mercury Lamps

By E. C. MARTT
K. GOTTSCHALK
A. C. GREEN

A new electrode design which markedly decreases end blackening throughout lamp life, increasing mean lumens by 28 per cent over a 9000-hour period, is described in this paper. The new electrode, which uses barium and calcium as the main emission materials instead of thorium, allows reduced starting voltage at low temperatures. Parameters of both lumen maintenance and low temperature starting voltage are illustrated for various argon filling pressures.

THE HEART of a mercury vapor lamp is the arc tube. The design of the arc tube determines lamp characteristics throughout life. One major improvement in the past was the increase in quartz arc tube dimensions by Noel.[1] This decreased the wattage dissipation per unit area of tube surface and increased lamp life as well as mean lumens. Elenbaas[2] has related luminous efficiency to watts loading of the arc, showing that efficiency increases with increased loading. The design engineer must balance the arc efficiency requirements against the practical limits of arc tube end-blackening and discoloration caused by excessive heat.

The commercial history of the jacketed mercury lamp design started with the H400-A1 (now H25HC) lamp introduced in 1935, and it was the forerunner of the present mercury lamps for general lighting. This lamp had a hard glass arc tube and electrodes with open, mandrel-supported tungsten coils coated with an oxide emission material. It gave good lumen maintenance, even by today's standards, and is still made today, with improvements, in the same basic form.

The 400-watt quartz arc tube was introduced in 1939 with an arc gap of only 70 mm compared to 150 mm for the glass lamp. The increased wattage loading caused a jump in luminous efficiency, as predicted by theory. The greater concentration of energy also affected electrode design. Since the arc in the quartz lamp is more constricted than in the H400-A1, the temperature of the hot spot at the electrode is much higher, and the H400-A1 electrodes cannot be used. The excessive heat causes the emission material to evaporate and darken the ends. In Europe, other types of oxide-containing electrodes were designed for the quartz lamp. These were generally of the pellet-type, in which a pellet of emission material was enclosed in a tungsten coil, but these were expensive and complicated to make. In the United States, the thorium-tungsten electrode[3] was adopted because of its low cost and simplicity of manufacture; also, in this early period, it outperformed lamps with oxide electrodes, both in lumen output and life.

With the introduction of quartz arc tubes, new lead sealing problems were encountered. The first type of seal used in this country was the graded seal, followed by the vacuum-made molybdenum foil seal. Most quartz lamps today use the mechanically-made foil seal (or pinch seal) which was developed in both Europe and the United States shortly after the war. It was introduced commercially in this country in 1949. After adoption of either the vacuum-foil seal or the mechanically-made pinch seal, lamp life improved to the point where lamps would continue to burn long after light output had depreciated below the economically useful point.

End-Blackening Effect

It can be shown that lumen depreciation of a relatively short arc tube is due largely to end-blackening of the arc chambers. This end-blackening is caused by the gradual evaporation of the electrode material and the deposit of this material on the ends of the arc tube. Fig. 1 illustrates how great the effect of end-darkening can be, by showing the theoretical per cent lumen loss for lamps that have been artificially blackened behind the main electrode tips. This loss is plotted against the ratio of the arc tube inside diameter to the arc gap. The value for the 400-watt H1 lamps has been experimentally verified. The lumen loss due to complete,

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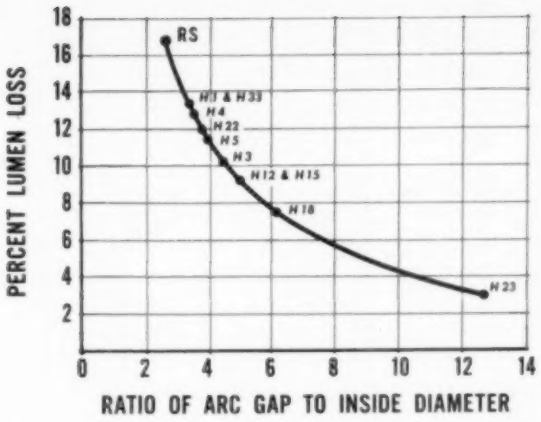

Figure 1. Theoretical per cent lumen loss for complete arc tube end-blackening behind electrode tips, for various mercury lamps, as a function of the ratio of arc gap to inside diameter.

theoretical end-blackening behind the electrode tips is about 13 per cent, comparable to 1500 hours of normal burning with thorium-tungsten electrodes, although the blackening in actual lamps is spread over a wider area and is not completely opaque. This curve also shows that improvement in electrode design, by reduction in the amount and/or type of evaporated material, can result in a major increase in lamp lumens.

Thorium-Tungsten Electrodes

A form of the thorium electrode, in common use in this country, is illustrated in Fig. 2. A tungsten center wire or shank is enclosed by a loose-fitting coil of tungsten wire with the turns nearly touching each other. Enough clearance exists between the inside of the coil and the shank to insert a thorium sliver. Spot-welding is done, transforming the thorium into a brazing compound between shank and coil, and the thorium acts as the electron emitter. This type of electrode is prone to transfer dense black metallic deposits onto the inside of the arc tube walls during starting and operating. However, it is relatively inexpensive to make, since the structure is simple. Also, since there are no carbonates to break down, it does not have degassing problems.

Improved Oxide Electrodes

European manufacturers have not used the thorium-tungsten electrode, but have developed a variety of oxide-electrode designs. These usually contain one or more of the oxides of barium, strontium, and calcium as the primary emitters, since these materials have a lower work function than thorium. Various other materials, such as tungsten powder, thoria, silica, etc., may be added as bonding materials. We have tested some of these designs as well as our own variations of such electrode types. However, these designs involved difficult and costly manufacturing parts and procedures, such as emission pellets, complex coils, expensive tungsten machining, and lengthy manual assembly. The designs that seemed most practical to manufacture did not fulfill performance claims.

The Osram Co. of Germany has developed an oxide-type electrode which gives excellent performance. While this electrode is considerably more expensive than our thorium-tungsten electrode, it is practical to make, and its general form has been adopted here. Not only is lumen maintenance greatly improved, but starting voltage at low temperature is significantly decreased, as was expected from use of oxide-coated electrodes. The starting voltage has been lowered sufficiently to give dependable starting directly from well-regulated, nominal 240-volt lines with a series reactor ballast at —20F. Because of the lower starting voltage requirements, the American Standards Association has issued a new lamp designation, H33, for 400-watt mercury lamps with this new electrode. Lamps with the new electrode operate equally well on ballasts designed for the thorium electrode lamps (H1-type), or on ballasts designed for these new H33 lamps. The new lamps are labeled H33-1 to indicate this interchangeability.

New Oxide-Electrode Construction

The construction features of the new electrode are shown in Fig. 2. The shank consists of a

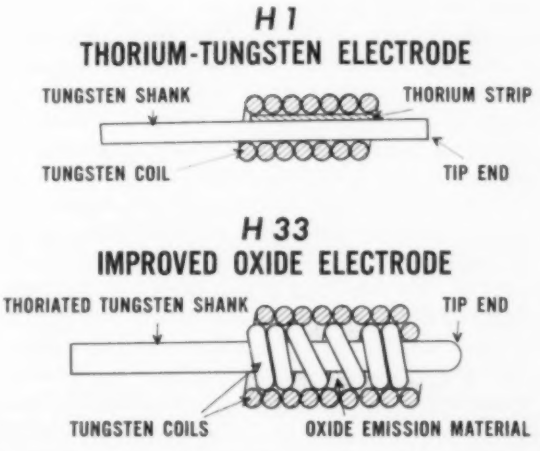

Figure 2. Cut-away drawings comparing construction of the H33 improved-oxide electrode and the H1 thorium tungsten electrode.

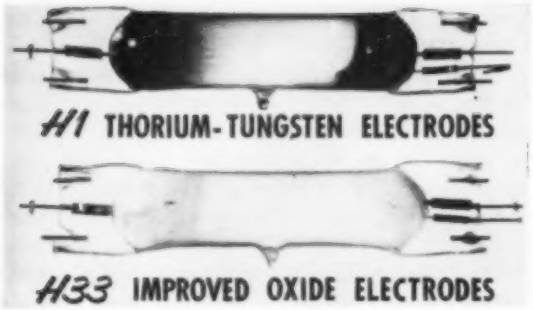

Figure 3. Comparison of typical end-blackening after 8000 hours burning of an H1 arc tube having thorium-tungsten electrodes with an H33 arc tube having improved-oxide electrodes.

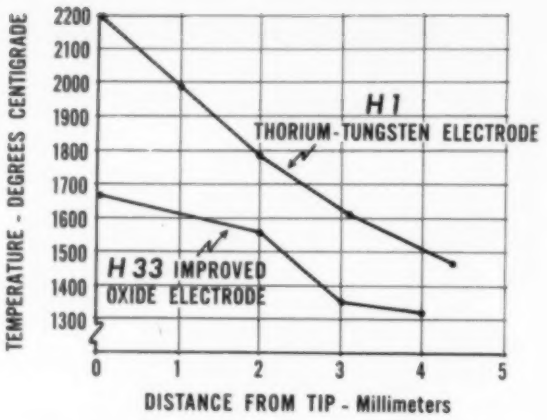

Figure 4. Comparison of average electrode temperatures of the H33 improved-oxide electrode and the H1 thorium-tungsten electrode.

cylindrical length of thoriated tungsten with a hemispherical tip. The inner coil, which has spaced turns, is press-fitted to the shank. The end turns are close-wound to exclude the arc, and thus avoid direct striking on the emission material pocket with consequent sputtering of material to the tube walls. Open turns at the center of the inner coil hold a copious supply of emission material which is slowly diffused to the outside of the electrode throughout lamp life. The screw-fitted outer coil is wound with the turns close together along the entire length in order to seal in the emission material. Both coils are made of tungsten. The entire construction is intended to control excess sputtering of material, yet provide enough emission material constantly, throughout life, to spread over the surface of the electrode and have an active emitting film.

Another very excellent feature is not only the limited sputtering, but the appearance of the deposited material on the arc tube wall. This is shown in Fig. 3 where an arc tube with improved-oxide electrodes is compared to one with thorium electrodes. This pair of arc tubes has burned 8000 hours. The sputtered material from the thorium electrode is much denser and is black, forming an opaque light barrier, while the improved-oxide electrode forms a much less dense milky film which is translucent.

The improved appearance is due primarily to the emission material. During starting, less of the oxide electrode structure (including tungsten) is sputtered away, since less energy is needed to draw out electrons from the electrode (due to a lower work function), while the arc is seeking to "hot spot." During lamp operation, the combination of lower work function and improved heat transfer characteristics of the metallic structure cause the temperature of the improved oxide-electrode to be much lower than that of the thorium-tungsten electrode. When the electrode temperature is decreased, the transfer rate of electrode material to the arc tube wall is decreased exponentially. This temperature difference is clearly shown in Fig. 4, which shows temperature as a function of distance from the electrode tip, for both thorium and improved-oxide electrodes.

Improved Lumen Maintenance

Comparison of per cent lumen maintenance during life for both thorium and improved-oxide electrodes, when burned in a vertical position, is shown in Fig. 5. The improved electrode lumen maintenance is obviously superior. In vertical base-up burning, the per cent depreciation is 3 to 4 times greater with thorium electrodes than with the improved oxide electrodes for equal burning periods.

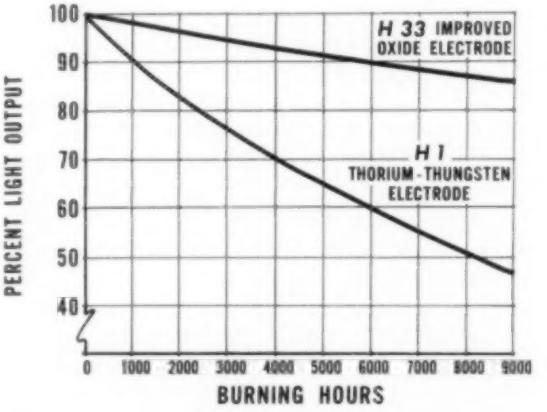

Figure 5. Lumen depreciation comparison of clear H33-1 400-watt lamps with improved-oxide electrodes and H1 thorium-tungsten electrodes. Vertical burning, five hours per start.

TABLE I

	100-Hour Lumens	9000-Hour Lumens	9000-Hour Life Mean Lumens
Thorium Electrodes	21,000	10,100	14,500
Improved-Oxide Electrodes ..	20,500	17,600	18,600

Table I compares initial (100 hour) lumens, lumens at 9000 hours, and mean lumens for 9000 hours life for both types of electrodes for vertical, base-up operation at 5 hours per start.

It can be seen that the thorium electrode has a small advantage in initial lumens at 100 hours. However, this difference in lumens disappears before 500 hours, and from 500 hours on, the improved-oxide electrode is superior in both total lumens and per cent of 100-hour lumens. Over a 9000-hour life, the improved electrode is superior in both total lumens and per cent of 100-hour lumens. Over the same period, the improved electrode lamp yields 28 per cent more mean lumens, and at 9000 hours, the improved electrode gives 74 per cent more lumens. In other words, after 9000 hours of operation, an improved-oxide electrode lamp gives as many lumens as an 1800-hour thorium electrode lamp.

Relation of Argon Filling Pressure to Starting Voltage and Lumen Maintenance

Virtually all mercury lamps, regardless of electrode type, have a low pressure of argon in the arc tube for use as a starting gas, since the mercury vapor pressure at room temperature is too low to allow breakdown at normal voltages. The amount of argon used must be carefully chosen, since it affects both lumen maintenance and low-temperature starting voltage. The argon gas reduces sputtering of electrode material while mercury vapor pressure is low, during the arc initiation and lamp warm-up. Thus, higher argon filling pressures promote higher lumen maintenance by limiting arc tube end-blackening. However, decreased argon filling pressures reduce the voltage requirements for low-temperature starting. Thus, a median value must be selected for optimum lumen maintenance with reasonable ease of low-temperature starting.

Effect of Argon Filling Pressure On Lamp Starting Voltage

Starting voltages presented in this paper were determined by the switch-start method, using a linear reactor set to deliver short circuit current equal to rated lamp operating current. Power is switched to the lamp through the reactor. If the lamp does not start in ten seconds, the power is turned off, the voltage is raised ten volts, the reactor reset, and starting attempted again. This process is repeated until the lamp starts. We have found that this method, when applied to a group of 25 or more production lamps, will repeat starting voltages within less than ten volts.

Probability plots are made showing the percentage of lamps starting at each voltage. Since, statistically, these sample lamps represent many thousands of others, probability plots never show 100 per cent starting, even though all of the samples may start. For the 50F curves, the minimum required starting voltages given represent 98 per cent starting, and for 0F and —20F, the minimum required voltages represent 90 per cent starting. The different percentages are used because we feel that for outdoor applications all of th minimum conditions affecting starting are less likely to occur simultaneously. In actual practice our experience has shown that this basis for establishing starting requirements has provided completely reliable lamp performance.

Let us look at the effect of argon pressure on lamp starting voltages. Fig. 6a illustrates the increase in starting voltage with increase in argon pressure for thorium electrodes in production lamps at three different temperatures: —20F, 0F, and 50F. At the nominal filling pressure of 25 mm, 265 volts will start the lamps at —20F. This starting voltage represents a considerable reduction at low temperatures over previous values, and the change can be mostly accounted for by the reduction of argon filling pressure.

Now, compare these values with the effect of argon pressure on lamps with improved-oxide electrodes. Fig. 6b illustrates the effect on starting voltage for the same three temperatures. The starting voltage is considerably lower for oxide electrodes under equivalent conditions. Again, however, rising pressure or decreasing temperature cause an increase in starting voltage. Argon filling pressure for the oxide-electrode lamps has been set at 23 mm. Measurements show a normal distribution of pressures around this center with limits of about 21 mm and 25 mm. Fig. 6b shows that 90 per cent starting is obtained at 227 volts at —20F, even if all the lamps are filled to the maximum of 25 mm and, of course, the majority are not. This value of 227 volts represents a 5 per cent decrease from 240 line volts now widely used in the United States. If the regulation of these lines is good, dependable starting in these lamps may be obtained with an economical series reactor ballast on these lines at temperatures down to —20F.

Listed in Table II are the respective starting voltage ratings at three temperatures for lamps with improved-oxide electrodes, with thorium elec-

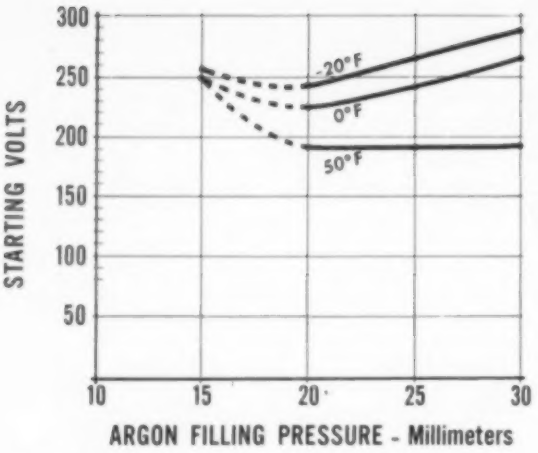

Figure 6a. Minimum required starting voltage as a function of tube filling pressure and ambient temperature for H1 lamps with thorium-tungsten electrodes. Twenty-five or more lamps at each pressure.

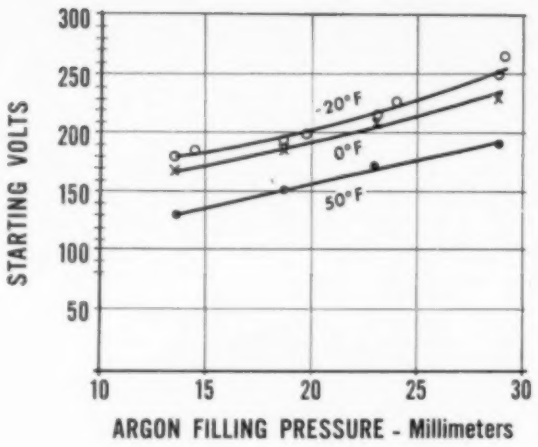

Figure 6b. Minimum required starting voltage as a function of arc tube filling pressure and ambient temperature for H33 lamps with improved-oxide electrodes. Twenty-five or more lamps at each pressure.

trodes, and thorium electrode lamps with reduced starting voltage. Voltages quoted are the minimum values needed for 90 per cent starting at 0 and —20F, and 98 per cent at 50F.

The low starting voltage for oxide electrode lamps at low temperatures is very significant, since it is only slightly more than the voltage required for lamp stability. The low starting voltage permits use of a simple reactor ballast on nominal 240-volt lines. Even if other types of ballasts are used, the over-all cost of the ballast can be reduced.

Effect of Argon Filling Pressure On Lumen Maintenance

Fig. 7 shows the relation of arc tube filling pressure to per cent lumen maintenance during life for vertical operation of thorium electrode lamps. The importance of filling pressure is clearly shown. For each one mm decrease in argon pressure below 25 mm, a corresponding loss of approximately one per cent in mean lumens occurs. Since cost-of-light varies directly with mean lumens, it is essential to keep the filling pressure as high as possible, consistent with reliable starting.

TABLE II—Minimum Starting Voltage Requirements.

	—20F	0F	50F
Improved Oxide Electrode (H33)	225	210	200*
Thorium Electrode (H1) Present ASA Value	290	265	200*
Thorium Electrode (H1) New Value	265	240	200*

*Although the arc will strike at a lower open circuit voltage, at least 200 volts are required for stable operation on a reference ballast.

Tests to obtain similar data for lamps with improved-oxide electrodes are under way. The curves in Fig. 6b show that starting voltage at —20F decreases about five volts for each one mm decrease in argon pressure. Preliminary tests indicate that the effect of filling pressure on lumen maintenance may not be as great as with thorium electrodes, but tests showing an accurate relationship are not completed.

It has been previously shown (Figs. 6a and 6b) that low temperature starting voltage decreases as argon filling pressure is reduced. For thorium electrodes, the decrease is about four volts per millimeter of argon. Thus, a five-mm decrease in pressure would result in a 20-volt decrease in starting volts, but mean lumens would decrease five

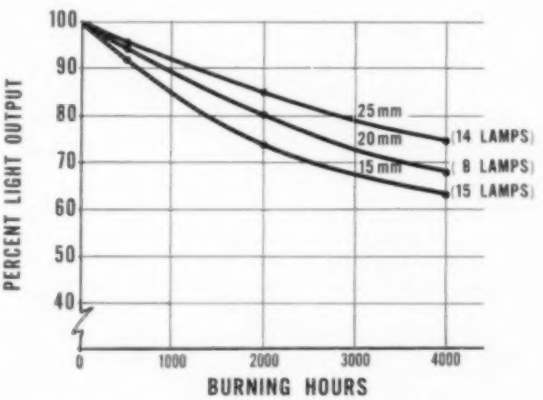

Figure 7. Lumen depreciation for clear H1 lamps as a function of argon filling pressure. Vertical burning, five hours per start.

per cent (and cost-of-light would increase by five per cent). Thus, a balance must be made between these two opposing factors. For the thorium electrode lamps, 25 mm argon filling pressure has been chosen as the center.

Summary

A new, improved-oxide electrode has been developed for the 400-watt quartz mercury lamp. The new electrode, while more costly to make than the tungsten-thorium electrode, substantially reduces arc tube end-discoloration, resulting in greatly improved lumen output throughout life. Mean lumens for 9000 hours life (more than two years of use in most applications) have been increased from 14,500 lumens to 18,600 lumens, a 28 per cent gain, and at the end of 9000 hours lamps with the new electrodes give 76 per cent more lumens than those with the old electrodes. It is shown that decreasing argon filling pressure in the arc tube causes a decrease in starting voltage at low temperatures, but also causes reduced lumen maintenance throughout lamp life. Starting voltage requirements have also been significantly reduced, allowing the use of simple reactor ballasts on well-regulated, nominal 240-volt lines at temperatures as low as —20F.

Acknowledgement

We wish to thank W. C. Matz of the Large Lamp Department, General Electric Co., for supplying starting and lumen maintenance data on lamps with thorium-tungsten electrodes.

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2. Elenbaas, W.: "Fifty Years of the High Pressure Mercury Vapor Lamp," *Philips Technical Review*, Vol. 18, No. 6, pp. 167-172 (1956/1957).

3. Gustin, D. S. and Freeman, G. A.: "Electron Emissive Cahtode," United States Patent No. 2,241,345, May 6, 1941.

DISCUSSION

M. C. UNGLERT:* The paper presents a fine summary concerning the performance of the new "oxide" electrode as well as the reasons for the improved performance as compared with the thorium type electrode used in the United States. Our data closely duplicate that presented in this paper, as can be noted in the paper by Till and Unglert.[1]

The section on the effects of argon fill pressure in a mercury lamp on cold temperature starting and maintenance is a well-presented summary of these results. However, we do not agree with the dotted portions of Fig. 6a. It has been our experience that the starting voltage at 0F and —20F will continue to decrease with decreasing fill pressure to a point below 10-mm fill before the starting voltage will increase, nor will 50F curve show an increase in starting voltage down to 10 mm. If an additional curve for 10-mm fill were drawn on Fig. 7, it would show even poorer maintenance than the 15-mm curve. For this reason it is not reasonable to design lamps with thorium electrodes which have fill pressures below 20 mm.

The results as outlined in Table II for "Thorium Electrode—New Value," duplicate values which we have proposed to the ASA Subcommittee on Mercury Lamps for several years. We feel that they should be adopted, especially in view of the very satisfactory performance of H1 lamps on nominal 300-volt open circut ballasts which may, in the case of low primary voltage, provide as low as 270 volts open circuit.

1. Till, W. S., and Unglert, M. C.: "New Designs for Mercury Lamps Increase Their Usefulness," ILLUMINATING ENGINEERING, Vol. LV, No. 5, pp. 269-281 (May 1960).

H. S. STRAUSS:* This paper presents excellent and thoroughly prepared data for the 400-watt H1 and H33 lamps. It should be of particular interest to mercury lamp users as it shows, in accurate engineering terms, an unquestionable superiority in performance of the H33 over the H1 lamp.

Can the authors state what argon fill pressure range is represented for the H1 curve in Fig. 5? From Fig. 6 it would seem to be somewhere between 20 and 25 mm. It is debatable whether 25-mm argon filling pressure should be used in H1 lamps. The data presented clearly show the effect of the variation in fill pressure. We have used 30-mm fill pressure in our H1 lamps and our data show that, for repeated samples of production lamps burning in the base-up vertical position on a five-hour-per-start cycle, lumen maintenance is improved by approximately seven per cent at 4000 hours and ten per cent at 9000 hours over the H1 curve shown in Fig. 5. Do the authors have any H1 lamp lumen maintenance data for 30-mm fill pressure to confirm this? Of course, as shown in the paper, low temperature starting voltage will be higher. However, outdoor ballasts now in use provide the necessary open circuit voltage for reliable starting of the 30-mm fill pressure lamps. Should the customer, therefore, not be given the benefit of the better lumen maintenance for the less expensive H1 lamps?

Fig. 2 shows the thorium silver extending the whole length of the electrode coil. We have found that better lumen maintenance is obtained, with no difficulty in starting throughout lamp life, if the thorium is controlled to exist in the rear portion of the coil. Have the authors observed this?

In conclusion, have the authors an explanation for the difference in initial (100-hour) lumen output between the H1 and H33 lamps as listed in Table I?

J. T. LAUGHLIN:** The introduction of the H33 lamp will be a boon to the entire mercury lighting industry. Higher lumen maintenance has been needed to enhance the economies of mercury lighting within the rated useful lamp life. Higher lumen maintenance will, in addition, extend the rated useful lamp life. These things are all good; however, the paper spotlights a change in mercury lamp design and manufacture which is most inconsistent with good lumen maintenance. There apparently has recently been a reduction in argon pressure, at least by one of the major lamp

*Westinghouse Electric Corp., Bloomfield, N. J.

*Duro-Test Corp., North Bergen, N. J.
*Sola Electric Co., Chicago, Ill.

manufacturers. This reduction has allowed lamp striking voltage requirements to be reduced from 300 volts to 265 volts (for H1, —20F striking).

The ballast industry would, under normal circumstances, be enthusiastic about lower striking voltage requirements with the attendant increase in ballast efficiency and decrease in ballast size. But, are the best interests of the user and the mercury lighting industry being served?

If the H1 lamp's acceptability were based on lumen maintenance alone, it would have marginal acceptability. Why then make H1 lumen maintenance worse by reducing argon pressure? The reason given is that a balance must be struck between lumen maintenance and striking voltage requirements. It would seem that a suitable balance was achieved many years ago, allowing the mercury industry to thrive. As recently as July 1958, the mercury lamp industry's striking requirements for an H1 lamp at —20F was 300 volts (ASA proposals). Such voltage requirements have not seemed to stunt the industry's growth.

Over the past two years, constant wattage ballasts, universally preferred, have been reduced more than 20 per cent in size, with marked improvements in lamp operating characteristics, particularly, lowered lamp current crest factor. Constant wattage ballasts have always offered the advantages of 300 volts for lamp striking. When then this precipitous reduction in argon pressure and lumen maintenance?

An interesting sidelight is that reduced argon pressure does not permit a reduction of voltages for 50F-operation of the H1 or H33 lamp. In the 50F-temperature range, the problem is one of providing enough voltage to sustain the lamp after it is struck, not one of striking the lamp. Still, lumen maintenance is sacrificed.

It seems unfortunate that the H33 was launched commercially with only 23-mm argon pressure. Granted, even with low argon pressure the H33 still has commendable lumen maintenance at 9000 hours—86 per cent, as shown in Fig. 5. But, why not send lumen maintenance over 90 per cent by using 28-mm argon pressure? Extrapolating from the curves of Fig. 6b, 28-mm agron pressure would allow the operation of H33 lamps down to approximately 30F, with the ballast voltage requirements still based on lamp sustaining voltage requirements, which the ballast must provide even under the most favorable striking voltage circumstances. The benefits of even greater increased lumen maintenance would then be available to the vast number of H33 applications at 30F and above.

It must be kept uppermost in mind that the H33 lamp wattage is as sensitive to changes in line voltage as the H1 has always been. If the H33, ballasted by a choke on a 240-volt line, is subjected to a five per cent line voltage change, lamp wattage will swing ten per cent. Likewise, a ten per cent line voltage change will swing lamp wattage 20 per cent. The advent of the H33 does not change this undesirable mercury lamp operating characteristic.

The paper points out that the H1 lamp could not use the oxide-coated H25 (A H1) cathode because of the higher temperatures to which the H1 arc tube subjected the electrode. It would be most valuable to determine if the oxide bearing electrode of the H33 is more vulnerable to damage by overheating caused by high lamp wattages than are the thorium tungsten electrodes.

It is important for the mercury lamp user to renlize that the H33 lamp does not alter the supply line problem of high inrush currents, power factor correction, leading power factor during lamp outage and that old bugaboo, proper tap selection, always associated with choke operation.

R. W. Haggstrom:* The authors are to be commended on reporting their successful development of improvements in mercury lamp design which have resulted in lower starting voltages and improved lumen maintenance. Before the introduction of the improved oxide electrode lamp, lumen maintenance was frequently related to the crest factor of the ballast. Since the authors made no reference to crest factor in their lumen maintenance tests, I presume that the "battle lines" once drawn on this issue have disappeared. The lumen maintenance curves shown are for operation of vertical burning lamps. What relationship to these curves, if any, will there be for the more popular horizontal burning lamps?

In reference to argon filling pressure and Fig. 7, one concludes that the present thorium electrode lamps are filled to 25-mm pressure, resulting, at the end of 4000 hours, with a light output of 75 per cent of initial. This conflicts with the comparison made in Fig. 5 where the thorium electrode lamp has 70 per cent of initinl light output at 4000 hours.

The advantages of low starting voltage lamps and 240-volt circuit reactors have been studied by various street lighting engineers from time to time. More often than not, disappointment followed. The great variation in line voltage is a difficult problem to surmount. The main concern here is the cost for proper installation of a "well regulated" line not influenced by daily, seasonal, and yearly fluctuations. To date, the only satisfactory solution to this problem has been the almost universal use of the constant wattage ballast.

Summing up, the new lamps with their better lumen maintenance and lower starting voltage will make mercury lamp lighting more competitive and more attractive to those desiring low cost lighting.

H. A. Breeding:** This interesting and informative paper is the harbinger of good tidings to the lighting industry in the form of better all-around performance and lower cost of light wherever the new oxide electrode 400-watt mercury lamp can be properly applied. It is stimulating to find in a new lamp a tool which performs as well after 9000 hours as the old design did after less than 2000 hours. This is bound to be a tremendous factor in lighting economics. I congratulate the authors on the fine improvements they have been able to build into the new oxide electrode lamp. Naturally these improvements raise a question about how soon other sizes will be available in the new design. Are the authors in a position to comment on this point now?

All of the life and lumen maintenance information presented in the paper is aimed at vertical operation and applies principally to indoor lighting applications. In outdoor lighting, at least for roadway lighting, which is a large and increasing part of the mercury lamp business, the lamps are almost universally operated in a substantially horizontal position. (This is done in order to take advantage of the better horizontal surface brightness resulting from the natural distribution of flux from lamps when operating in this position.) Can the authors at this time present data which show the results with the new lamp operating at ten hours per start in the horizontal position?

In the outdoor lighting business, a large new market appears to be developing along with the new interstate highway system where series circuit lighting has already been applied to several miles of new highways. The use

*Jefferson Electric Co., Bellwood, Ill.
**Outdoor Lighting Dept., General Electric Co., Hendersonville, N. C.

of series circuits offers considerable economic advantage where there is no secondary distribution existing, as is often the case along these new highways and their approaches.

Increasing use of series circuits in highway lighting, along with the announcement last year of a lamp for use without cutouts in straight series circuits, indicates the advantages which this new electrode should add to the straight series H1BA lamp. Can the authors estimate when this lamp might be listed with the new cathode?

In the outdoor lighting multiple circuit field, full economic advantage of lower starting voltages cannot be realized until ballasts are redesigned for the lower starting voltages now standardized for both thorium-tungsten and the new oxide electrode lamps. The new values mean that ballast kva can and will be substantially reduced in the near future, thus contributing to the further lowering of cost of light.

The announcements included in this paper are most certainly a milestone in the lighting business and it is fine to see this data made available so that it may be widely understood and used to assist progress.

R. R. Wylie:* This is a clear, concise exposition of the development and characteristics of the H33 line of lamps. Only two basic questions remain unanswered.

(a) In Fig. 5 a comparison is made of lumen maintenance of the H1 and H33 lamps burned in a vertical position. The authors' company has published data which claim that maintenance of H1 lamps, when they are burned in a horizontal position, is greatly improved over the H1 curve presented. Have sufficient data been accumulated on the H33 lamp operated in a horizontal position so that reliable data, such as is presented for the H33 in a vertical position, can be published?

(b) Relative to the relationship between low starting voltage and low temperatures, is it expected that under severe low temperature (—30F) starting conditions stabilization of horizontally operated lamps may be difficult to achieve with the H33 or lamps of comparable cathode construction?

E. C. Martt, K. Gottschalk and A. C. Green:** We wish to thank the discussers for their criticism and comments.

Mr. Unglert states that he is not in agreement with the dotted line portion of Fig. 6a which indicates erratic starting for thorium electrode lamps having low argon pressures. Our tests at 15 mm show that a number of lamps do not start because the arc is so diffuse that a hot spot cannot form. The difference between his results and ours can likely be accounted for by differences in electrode mass, or in portions of it. As he points out, however, this low pressure is not used in practice, and so the discrepancy is academic.

Mr. Strauss and Mr. Laughlin question the proper choice of argon filling pressure as it affects both lumen maintenance and starting voltage. Our design filling pressure has always been 25 mm, although in the past it has varied more widely than we would like, and this variation has affected starting voltage most strongly, since a 90 per cent starting criterion is used, while mean lumen changes tend to average out. Recently we have improved both our measurement and control techniques of argon pressure so that the variation is much less. Better control of argon pressure, plus other measures not described in this paper, have brought about a marked reduction in starting voltage for the H1 lamp. During the six-month interval between the time this paper was prepared and presented, we have increased the lumen maintenance of the H1, so that it is now 75 per cent at 4000 hours and 66 per cent at 6000 hours. These are higher values than are shown in Fig. 5, and are changes brought about without changing argon filling pressure. The values shown in Fig. 7 are still valid, if argon pressure is the major variable involved.

Messrs. Strauss and Laughlin ask why we should not use 30-mm argon pressure instead of 25-mm for the H1. This would keep the starting voltage at the old level, and lumen maintenance would be improved. This is a surprising request from a ballast manufacturer, since in the past we have always been under pressure to reduce the H1 starting voltage, which for —20F is considerably above the voltage required for lamp stability. Lower open-circuit voltage allows a reduction in ballast cost, and, in most cases, ballast losses. To many users these factors are of considerable importance, since they raise the entire system efficiency. Since we were able to reduce starting voltage and at the same time increase mean lumens, we felt that these changes would be welcome. If a customer desires greatly superior lumen maintenance, plus still lower starting voltage, we recommend use of the H33 lamp.

Mr. Laughlin correctly points out that the reduced H1 starting voltages are of use only for low temperature application, since for 50F and above the voltage required for stability is higher than the starting voltage. Since the H1 (and other mercury lamps) are intended for a wide range of ambient temperatures, varying from a hot summer day to —20F in the winter, it is obvious that the limiting conditions determine the requirements that the lamp designer must meet. Again, the H33 lamp comes close to realizing the discharge lamp ideal of requiring a starting voltage near the level of the stability voltage.

Mr. Laughlin asks why the argon pressure of the H33 should not be set high in order to obtain better lumen maintenance. The pressure of the H33 lamp was set at 23 mm in order to allow starting at 20F on a well-regulated 240-volt line, since this line voltage is now an accepted nominal. Tests are under way to obtain lumen maintenance vs argon pressure data as was presented in Fig. 7 for H1 lamps. Theory tells us that this electrode should be less sensitive to variations of argon pressure, and preliminary test results confirm this. Mr. Laughlin is only speculating when he suggests that lumen maintenance at 9000 hours would increase from 86 per cent to over 90 per cent if argon pressure were increased to 28 mm. It seems to us that since the effect of argon pressure on H33 lumen maintenance is relatively small, and the starting voltage effect is relatively great, that 23 mm is the best choice of pressure.

We referred in our paper to the use of simple reactors to ballast H33 lamps to show how simple their operation could be under suitable conditions. As Mr. Haggstrom and Mr. Laughlin imply, variations in line voltage will affect the H33 lamps just as much as the H1, when operated from a reactor. However, if a customer desires some other type of ballast, we understand that the lower starting voltage would result in savings there, also.

A question was asked as to whether or not the H33 could tolerate wide limits of starting current, lamp wattage, etc., compared to the H1. As far as the electrode is concerned, we believe it can. However, most of these limits affect quartz loading, seal design, etc., and so must be considered for the lamp as a whole. We propose at this time to use the same limits for the H33 and H1.

Mr. Breeding and Mr. Wylie have asked if H33 lamps

*Sylvania Electric Products Inc., Salem, Mass.
**Authors.

show a difference in lumen maintenance between vertical and horizontal operation. Since the lumen maintenance of the H33 lamp is so high when burned vertically, there is little room for improvement for horizontal operation. Tests are under way to determine the possible gain, but since any difference is likely to be small, we do not expect an early answer to this question.

Mr. Strauss has asked about placement of thorium in the H1 electrode, as shown in our Fig. 2. He states that he has found an optimum position for the thorium as it affects lumen maintenance. This is, incidentally, one of the many factors besides argon filling pressure for the H1 lamp which affect lumen maintenance. Fig. 2 is not intended to give exact details of our present H1 electrode, but represents a typical design. We have found that thorium placement in the front end of the coil is better for our electrode, but each manufacturer must find the optimum position for his own design.

Mr. Strauss has also asked why the initial lumen rating of the H33 is lower than the H1. This difference has always existed between the two types, but in years past has been as high as 2000 to 3000 lumens. The present difference is only 500 lumens, or 2.4 per cent. We do not have data at this time to explain the reasons for the difference. Mr. Haggstrom points to an apparent discrepancy between H1 maintenance curves shown in Figs. 5 and 7. Fig. 7, which shows how lumen maintenance varies with argon pressure, is an engineering test designed to show the relative effect of the variables tested. Due to normal variations, an engineering test usually does not exactly duplicate a published curve, based on many more lamps. Thus, we do not expect the top curve of Fig. 7, and the bottom curve of Fig. 5, to agree exactly, even though both groups of lamps are filled at 25-mm argon pressure.

Mr. Haggstrom asks if lamp current crest factor is as important for the H33 lamp as for the H1. Since high crest factor causes an increase in end blackening in the H1, and since end blackening is greatly reduced in the H33, we expect that the crest factor effect will also be less. We have tests under way to determine the effect of crest factor on H33 lamps.

Mr. Breeding asks when the H1BA lamp for straight series operation of mercury lamps will be available with the new electrode. The H33 lamp, of course, would perform quite well under the same conditions. Listing depends upon market demand.

Mr. Wylie asks if stabilization of horizontally operated H33 lamps is difficult to achieve at —30F. By stabilization, we assume he means warm up to rated voltage. We have not tested at —30F, but we are certain that they would operate satisfactorily in enclosed luminaires under these extreme conditions, although higher starting currents may be necessary for the H33 than for the H1. In this country, warm up at —30F is largely academic. Even —20F, the lowest temperature for which mercury lamp characteristics are listed in ASA standards (and proposed standards) is seldom encountered in the United States by the vast majority of mercury lamp users. In fact, weather data show that for the major U. S. cities there are only a few days per year when temperatures below zero are reached. Operation at —30F would require special ballasts, since most ballasts in this country are designed to start lamps only to —20F. We regard the —30F operation as a special condition that requires special testing.

Custom-Made Chandelier Forms Unique Glassware Display

Unique lighted crystal chandelier, constructed of $2814 worth of 540 examples of the finest cut glass produced in Stourbridge, England, was used in conjunction with a special display of fine china and crystal at Harrods' Department Store, London, England. The chandelier, 93 inches in length and 23½ inches in diameter at the widest point of its framework, was constructed of seven "wheels" arranged in the form of a pyramid. Glasses are secured by hooks placed at the spokes of each "wheel," each hook supporting three glasses. Lighting is from a 100-watt incandescent lamp housed in the crystal vase at the base of the chandelier and eight 60-watt incandescent lamps mounted on the chandelier stem inside the bell-shaped perforated metal framework connecting the lowest wheel with the bottom vase. Cost of the framework and wiring for the main support exceeded $1800. Chandelier designed by J. D. Cain, Display Manager at Harrods'; photo and data courtesy of Harrods' Major Household Appliances Buyer, W. M. Merrell.

New Designs for Mercury Lamps Increase Their Usefulness

By W. S. TILL
M. C. UNGLERT

Significant results in the continuing research in mercury lamps are reported in this paper. In the design of quartz mercury lamps, a new electrode with a new type of oxide emission material brings about improved lumen maintenance and easier cold-weather starting. The new electrode, together with other improvements, results in longer life ratings. Cost studies show that the new design saves approximately 18 per cent in annual cost of light for typical installations. Also described are other improvements in mercury lamps.

RECENTLY some very important improvements have been achieved in the design of quartz mercury lamps. A new electrode design together with a new type of oxide emission material has permitted greatly increased lumen maintenance in such lamps, giving them the best maintained light output throughout life of any vapor lamp including fluorescent tubes. At the same time it has provided much easier starting especially at cold temperatures. Because of this, the American Standards Association—recognizing the significant lowering of starting voltage requirements for this new type of lamp—has assigned the characteristic number "33" to designate lamps of the 400-watt size having this electrode. In addition to the development of the new electrode, there have been other improvements affecting almost all types of mercury lamps. These include better methods of sealing the ends of the quartz arc tube, simplification of arc tube support structure, new types of resistors, greater use of hard glass outer envelopes, improvements in the base, and several other design changes.

The use of the new electrode, together with the other improvements, has resulted in the publication of much longer life ratings. For instance, the regular H1LS (E-H1) mercury lamp has been rated in the order of 6000-7000 hours economic life, whereas the newly designed comparable H33-1CD lamp is now rated at 9000 hours economic life. The average life to burn-out for both types is of course much longer than this. The increased economic life rating for these new lamps is supported by cost studies which show that the new design saves approximately 18 per cent in annual cost of light depending upon the type of installation.

Description of New Construction

Comparison of Electrode Types

The first material tried as an emission source for quartz mercury lamps consisted of oxides similar to those used in glass arc tube lamps such as the H25DE (A-H1-WD). Unfortunately, the oxide material used in these electrodes vaporized relatively rapidly and although suitable for glass arc tubes proved excessively corrosive when used in quartz arc tubes. A diagram of such an electrode is shown in Fig. 1a. Quartz mercury lamps became practical around 1939 only because of the development of the thorium electrode.[1] In the construction of the thorium electrode, as will be noted in Fig. 1b, a tiny sliver of metallic thorium is placed beneath a tungsten coil and securely welded. Only one coil of tungsten is generally used over the thorium.

The new electrode, as shown in Fig. 1c, consists of two coils, one within the other. The central coil has open turns of tungsten wire and therefore pro-

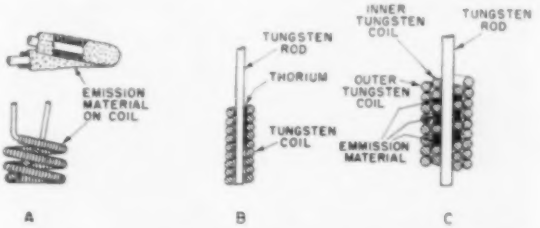


Figure 1. Types of electrodes used in mercury lamps: (A) oxide-coated tungsten coils, used in lamps having glass arc tubes; (B) thorium sliver welded beneath tungsten coil, used in quartz arc tubes; and (C) oxide-embedded double-coil electrode recently developed for quartz arc tubes.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. AUTHORS: Westinghouse Electric Corp., Bloomfield, N. J.

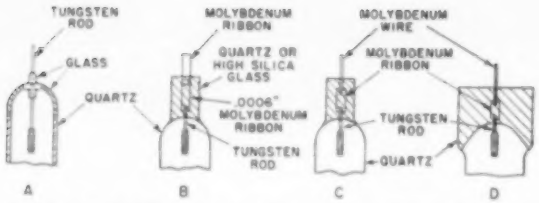


Figure 2. Types of seals developed for use in mercury lamps: (A) glass-beaded tungsten "graded" seal; (B) vacuum-shrunk molybdenum foil seal; (C) "pressed" seal (narrow); (D) "full press" seal.

vides space for the deposition of special chemical materials which make up the new emission mixture. The blending of these ingredients was developed by scientists at the Osram Co. in Berlin, Germany. Materials consist essentially of a mixture of oxides together with small amounts of tungsten. The procedure used in treating and activating such electrodes is critical. For more information concerning these electrodes, the reader is referred to the paper by Martt, Green and Gottschalk.[2]

New Quartz Sealing Techniques

The evolution of various types of quartz seals is shown in Fig. 2 and has been partially described in earlier papers.[3,4] Previously these seals were made either with three separate pieces of quartz, or with one piece having reduced diameter at each end. The latest step has been to redesign the arc tube so that the seal could be made directly from a full size piece of quartz tubing without the necessity for adding extra small pieces or reducing the diameter of the main quartz body. This improvement has resulted in a more uniform product and hence a finished lamp of generally better quality.

Simple Arc Tube Support Structure

The simplification of the mount structure is shown in Fig. 3, which compares the new and old methods of supporting arc tubes. The new design consists of a flat metallic nickel ribbon which passes over both the front and back of the pressed end of the arc tube and is welded to the supporting rods at each side. This improves the lamp in three ways:

(1) the smaller number and area of metal parts reduces the amount of gaseous impurities that can be released from the support structure during lamp operation, resulting in better life and maintenance.

(2) Simplified structure requires a smaller number of welds and hence reduces the chances of a weld failure.

(3) The smaller area of supporting parts results in a smaller percentage of the light from the arc tube being absorbed. This becomes more important in the case of a phosphor-coated outer bulb which may subject the light from the arc tube to multiple reflections thus allowing greater opportunity for absorption of light by the supporting structure.

New Materials for Resistors

As shown in Fig. 4, lamp resistors have changed from a rather large wire-wound type to a special ceramic type made of magnesium titanate. Since the older type wire-wound resistors were relatively large and bulky, they required very good welds to the side supports, or some other method of fastening, to avoid their breaking loose during transportation. The small size and light weight of the new resistors make them much better able to withstand rough handling.

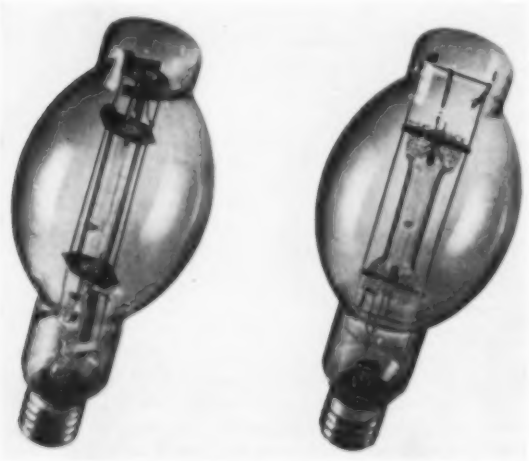


Figure 3. Simplification of mount structure. New design is stronger and intercepts less light.

Figure 4. Comparison of old (large) and new (small) starting resistors.

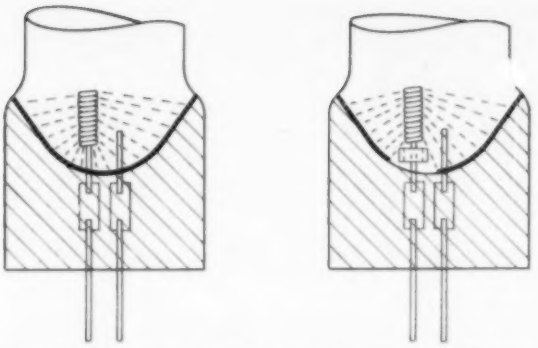


Figure 5. Quartz bead used with thorium electrode prevents deposit of emission material, which mercury can wet, in critical area between starting and adjacent operating electrode.

Quartz Collar for Electrodes

Fig. 5 is an illustration of a quartz collar or bead which was developed for use with the thorium type electrode to prevent mercury from creating a conducting pathway from the starting electrode to the operating electrode. The thorium electrode occasionally sputters enough thorium and tungsten onto the arc tube area behind the electrode so that the mercury in the lamp can wet the surface of this deposit to form a bridge. This short-circuits the starting electrode causing the lamp to become difficult to start or inoperative under certain conditions. The short-circuit occurs only when the lamp is burned in a position between horizontal and base-down but never vertical base-up. The reason for this is that mercury will not condense in the area of the starting electrode when the lamp is burned base-up, since this section of the arc tube remains hot longer than other portions of the arc tube, and so the mercury condenses at the other end where it can not cause trouble. The quartz collar prevents mercury from shorting the electrodes in two ways:

(1) Thermally retains heat and thus discourages mercury from condensing near the operating electrode.

(2) Physically tends to prevent material sputtered from the thorium electrode from covering this section of the arc tube behind the electrodes, as shown in Fig. 5.

The use of this collar is continued in lamps with thorium electrodes but is unnecessary in lamps with the new oxide electrode because characteristics of the new material are such that mercury does not wet it.

Hard Glass Outer Envelopes

In recent years there has been a trend toward greater use of hard glass outer envelopes. These resist thermal shock and are not attacked by sulphur dioxide or other corrosive gases in the atmosphere.[5] Almost all sizes of mercury lamps are available with hard glass bulbs. At present, all H33 lamps are made only with hard glass.

In street lighting service soft lime glass is still considered adequate for ordinary mercury lamps. This is not always the case, however, and since the new H33 lamps will probably be kept in service much longer than previous types it is undoubtedly good insurance to have the best possible outer bulb material. In industrial applications the widespread use of ventilated luminaires permits much greater circulation of air past the lamp than with enclosed or non-ventilated luminaires, so that atmospheric corrosion can be an important factor. For this reason and because the lamps are often operated at high ambient temperatures, it is best practice to use only hard glass mercury lamps in most industrial installations. If lamps with soft lime glass bulbs are used, systematic relamping is strongly recommended for the period of 6000-10000 hours, to prevent deterioration of the bulbs. If hard glass outer envelopes are used, corrosion simply does not occur, and the time of lamp replacement depends more on convenience and economies than on necessity.

Date-Coded Bases for Recording Date of Installation

As shown in Fig. 6, some manufacturers are providing mogul screw lamp bases which have digits imprinted into the brass metal of the base. This allows the maintenance man or electrician to use a knife, screwdriver, or other sharp tool to make

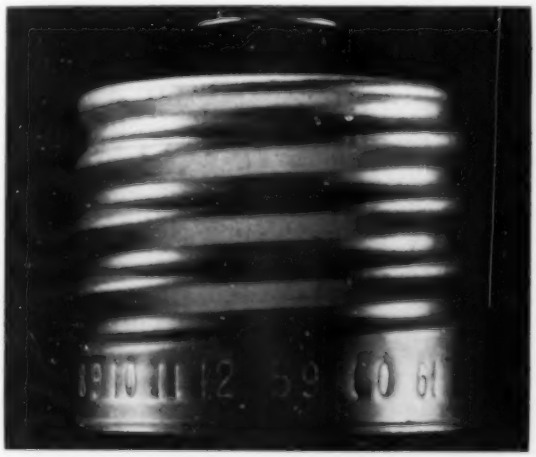


Figure 6. Mogul screw base with numbers corresponding to months and years. Dates of installation and removal can be recorded by making appropriate scratch marks in the metal.

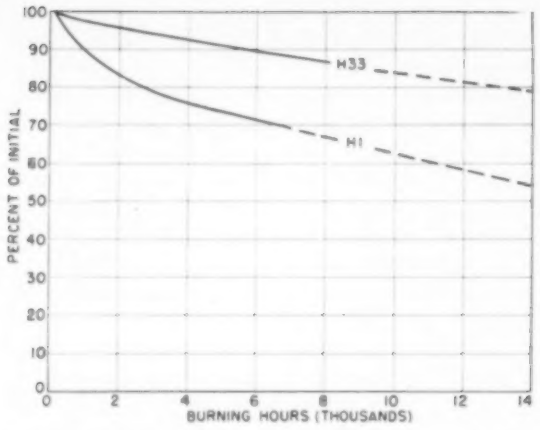


Figure 7. (Top) Lumen maintenance for 400-watt H33 mercury lamps having new oxide-embedded emission material; (Bottom) Lumen maintenance for 400-watt H1 mercury lamps having thorium electrodes.

a scratch mark opposite the symbols for year in which the lamp is installed.

The number-marked base allows the customer to keep track of early failures, if any, as well as to keep track of any lamps which should be removed because they have been in service for a long while. At the time that luminaires are cleaned, the lamp base can be inspected to determine how many years it has been in service. If several years, it should probably be discarded, even if of latest design.

Technical Characteristics

Improved Lumen Output Throughout Life

The principle improvement in mercury lamp characteristics, as contained in lamps of the 400-watt H33 design, is that of greatly improved lumen maintenance. This is the result of two factors. First, the rate of evaporation of material from the new electrode is greatly retarded, and secondly, any material that does evaporate is of a whitish color rather than black as with the thorium cathode. These factors have resulted in a major improvement in maintenance, as brought out in Fig. 7, which shows a generalized comparison of the maintained light output throughout life of lamps made with the old thorium electrode design as compared to those made with the new special oxide electrodes. Fig. 8 shows a photograph of lamps of the old and new design, both of which have operated for 7000 hours. Note the reduction in blackening of lamps of the new electrode design.

Reduced Starting Voltage Requirements

Of outstanding importance is the fact that the new improved mercury lamps start much more

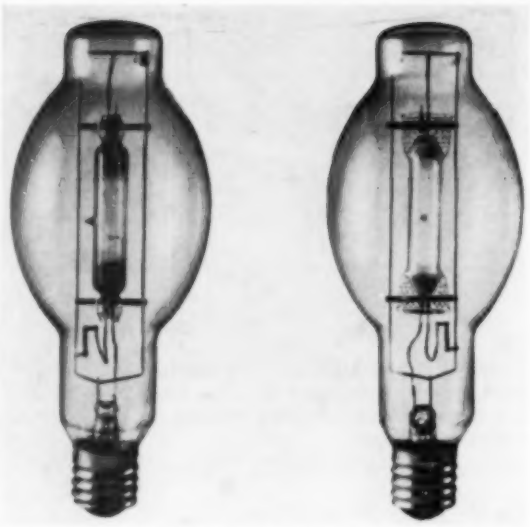


Figure 8. Left, 400-watt H1 mercury lamp after 7000 hours burning. Right, 400-watt H33 mercury lamp after same number of hours operation under same conditions. Note reduction in blackening of the arc tube.

readily than the regular thorium electrode types. This is shown in Fig. 9, which shows the starting voltage requirements as a function of temperature. H33 voltage values at the colder temperatures are substantially lower than those for H1 lamps, and similarly the experimental H12LG values are lower than those for regular H12 lamps. This is the result of the lower work function of the new oxide cathode as compared with that of the thorium electrode. Values below 220 volts are not shown because this is the minimum voltage ordinarily

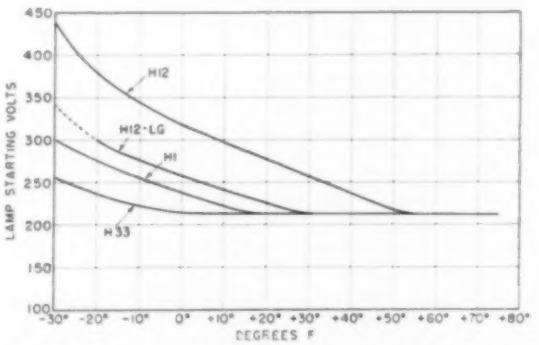


Figure 9. Lamps with new oxide embedded electrodes (H33, H12LG-Exp.) start more readily than comparable lamps with thorium electrodes (H1, H12). Values shown are neither minima nor maxima. Good performance will be obtained if the open circuit voltage at the lamp is within ±5 per cent of the values given to provide for line voltage variation, ballast tap selection, and wattage control.

TABLE I—Voltage Required to Start H33 Lamps

	Temperature in Degrees Fahrenheit				
	0	—10	—20	—30	—40
Average of 53 lamps	187	197	204	220	238
90 per cent of lamps starting	210	221	225	240	267

Test procedure: lamps are held at the test temperature for a minimum of two hours. Then they are operated from an outdoor type ballast having a sinusoidal open-circuit voltage wave-form. The supply voltage is brought up in 10-volt steps and held 15 seconds at each voltage. When the lamp lights, it is operated until fully stabilized. When new lamps are used, they are seasoned two hours before beginning the test.

TABLE II—Voltage at Which Arc Extinguishes

	H33	H1
Average lamp operating voltage (for reference).....	135.9	134.9
Average supply voltage at which arc is extinguished	168.7	172.8

Test procedure: lamps are operated from a standard reactor set at 45 ohms impedance. Supply voltage is lowered from 220 volts to the extinguishing point within 5 seconds.

recommended for stable operation and protection against outage caused by voltage dips.

The values given in Fig. 9 allow for a 5 per cent drop in normal open circuit voltage. Actual statistical results are given in Table I, which shows the open-circuit voltage requirements for large groups of H33 mercury lamps on both an average basis, that is the voltage which on the average started the lamps at a given temperature, and also on the basis of 90 per cent of the lamps starting instantly at the voltage chosen. This latter value is considered representative of lamp performance, since any mercury lamp not starting immediately usually starts within a few seconds as long as available voltage is equal or close to that recommended for a given temperature.

Stability During Voltage Dips

Tests were made to determine whether the new H33 lamps could withstand very much greater drops in open-circuit voltage as compared with H1 mercury lamps. Very little advantage results. The average difference is in the order of 4 to 5 per cent in favor of H33 lamps. Table II shows these results.

The minimum open-circuit voltage at which a mercury lamp will remain stable is of interest to ballast manufacturers, since it determines the lower limit toward which they may work and thus assures them of the degree of safety factor their ballasts will have for any particular condition of operation.

Mortality Data

All indications are that the mortality curve for H33 mercury lamps and other types of similar improved electrode design will be good as or better than the curve for the H1 thorium electrode type mercury lamps. Thus far none of the new oxide-type lamps tested in laboratory or field service have yet burned out as a result of cathode failure. Many lamps have been burned in excess of 12,000 hours and are still operating. Tests of these electrodes have shown no deterioration as a result of repeated starting such as is commonly observed with ordinary oxide type electrodes as used in H25DE (A-H1-WD) lamps.

Fig. 10 shows the present published survival curve for 400-watt H1 quartz mercury lamps.[6] This curve is drawn very conservatively, as actual experience in hundreds of installations involving thousands of lamps has actually shown that the more typical curve would pass through points about about midway from the present curve and 100 per cent, as shown by the dotted line. No factors have been discovered up to 12,000 hours which would prevent H33 lamps from following the same mortality pattern as H1 lamps. It is too early to be certain of the shape of the curve beyond this point, but it is expected to resemble that for H1 mercury lamps.

Economic Results and Comparisons

Longer Useful Life

The combination of a favorable mortality curve and an extremely favorable lumen maintenance curve (Figs. 10 and 7 respectively) make it apparent that the new H33 improved electrode mercury lamps have a very long useful life, much longer than for the thorium electrode types. It pays to burn the new lamps longer because their light output stays high for a much longer time. The lumen maintenance curve (Fig. 7) for the new lamps is actually better than that of any other vapor lamp source. This includes all types of fluorescent lamps.

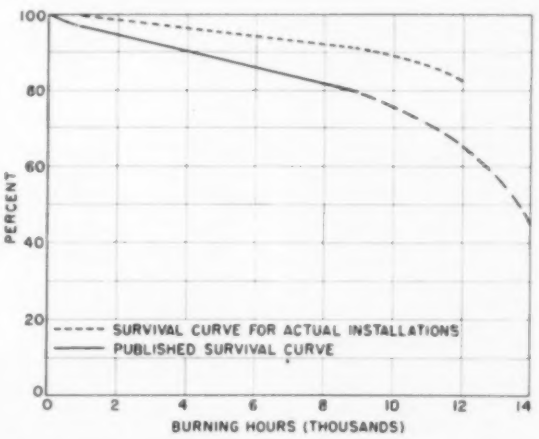


Figure 10. Survival data for 400-watt quartz mercury lamps.

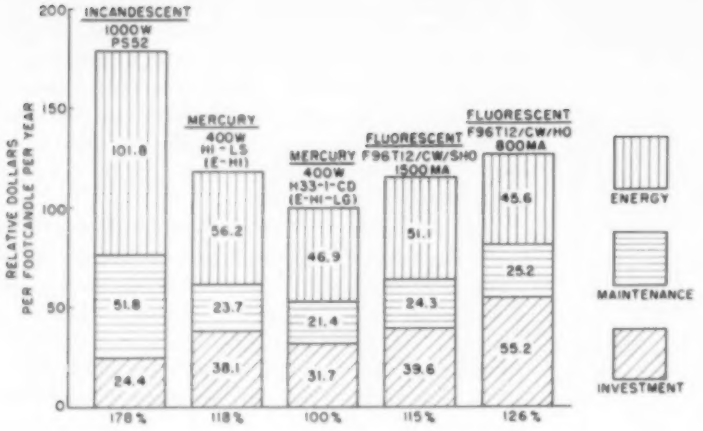


Figure 11. Relative annual cost of light for a high-bay industrial area, type "A" room (see Table III).

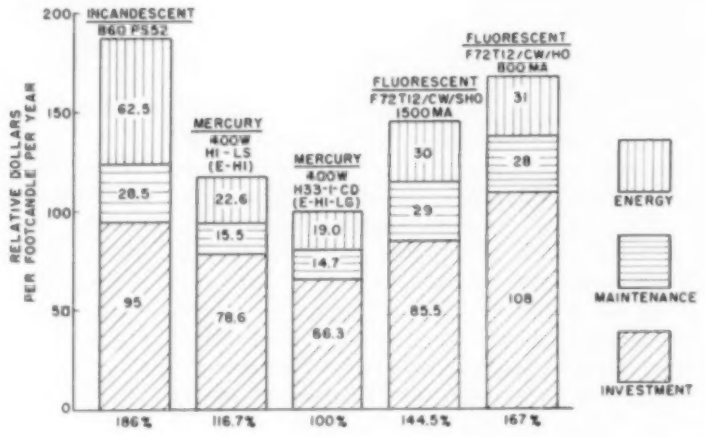


Figure 12. Relative annual cost of light for street lighting (see Table IV).

TABLE III—Cost of Lighting Analysis for Industrial Area. 200 x 120 x 27 feet x 19-foot mounting. Ceiling reflectance, 50%; walls, 30%. $2.50 labor cost to replace one lamp at random, cleaning cost $1.00 per luminaire, 2 cleanings per year of 4000 burning hours, power 1¢/kwhr.

	1	2	3	4	5
1. Type of lamp	Incandescent	Mercury	Mercury	Fluorescent	Fluorescent
2. Lamp description	1000-watt PS52	400-watt H1LS	400-watt H33-1CD	1500 ma F96T12 cool white extra-high-output	800 ma F96T12 cool white high-output
3. Type of luminaire (ventilated	High-bay	High-bay	High-bay	Industrial	Industrial
4. Number of lamps per luminaire	1	1	1	2	2
5. Rated initial lamp lumens per luminaire	23,000	21,000	20,500	26,500	14,600
6. Lamp life	1000	13,700	13,700	7500	13,000
7. Watts per luminaire (including auxiliary)	1000	425	425	480	235
8. Coefficient of utilization	.73	.74	.74	.66	.66
9. Maintenance factor	.75	.634	.783	.70	.70
10. Number of luminaires	120	120	120	120	120
11. Average footcandles maintained	62.95	49.26	59.39	61.22	33.73
12. Net luminaire cost (ea.)	$16.00	$26.25	$26.25	$68.00	$52.00
13. Net additional accessory cost per luminaire	$10.00	$20.65	$20.65	$1.00	$1.00
14. Estimated wiring & installation cost per luminaire	$38.00	$30.00	$30.00	$30.00	$23.00
15. Net initial lamp cost each (list less 30% plus tax)	$2.10	$15.23	$17.50	$4.17	$2.70
16. Total initial cost less lamps	$7,680	$9,228	$9,228	$11,880	$9,120
17. Annual fixed charges (15% of above)	$1,152	$1,384.20	$1,384.20	$1,782	$1,368
18. Total annual maintenance labor cost	$1,440	$327.50	$327.50	$560	$425
19. Total annual maintenance cost	$2,448	$860.55	$940	$1,093.76	$624.80
20. Annual energy cost	$4,800	$2,040	$2,040	$2,304	$1,128
21. Total annual operating cost	$7,248	$2,900.55	$2,980	$3,397.76	$1,752.80
22. Total annual cost	$8,400	$4,284.75	$4,364.20	$5,179.76	$3,120.80
23. Annual cost per footcandle	$130.27	$86.99	$73.48	$84.61	$92.52
24. Relative annual cost per footcandle	178%	118%	100%	115%	126%

Because of mortality and lumen maintenance factors, the economic life of the new H33 mercury lamps is calculated to be in order of 9000-10000 hours for most installations as compared to 6000-7000 hours for H1 lamps of the conventional design.

Cost of Light

Comparative studies of the cost of light for H33 and H1 mercury lamps and other light sources are given in Figs. 11 and 12, based on data from Tables III and IV. These are figured on the basis of random relamping for both industrial and street lighting installations.

Since the manufacturers' published life ratings for mercury lamps seem to bear little if any relation to published mortality curves, the authors have used as a basis for the calculations in Tables III and IV the actual published curves rather than the artificial ratings which prevail. The average life to burn-out is taken at the 50 per cent point of the curve, which is 13,700 hours. It should be noted that even this long life is conservative since actual performance is generally better than this, as shown in Fig. 10. The Pennsylvania Turnpike has records of a sizeable percentage of mercury lamps which have operated over 30,000 hours, and one that was still burning at 81,554 hours. In any case, whether the reader will agree that the use of 13,700 hours for average life is correct or not, it puts mercury lamps on the same relative basis as the other light sources used in the calculations. It is generally accepted practice to rate incandescent and fluorescent lamps at 50 per cent of their mortality curve.

The cost study summary in Fig. 11 shows that for industrial lighting the new type H33 lamps have an advantage of 15 percentage points over extra-high-output 1500-milliampere fluorescent lamps for the particular case chosen. This was a very wide room. For high narrow rooms there is an even greater advantage. For street lighting the advantage over the extra-high-output fluorescent is in the order of 45 per cent, and 17 per cent over H1 mercury lamps as shown by Fig. 12.

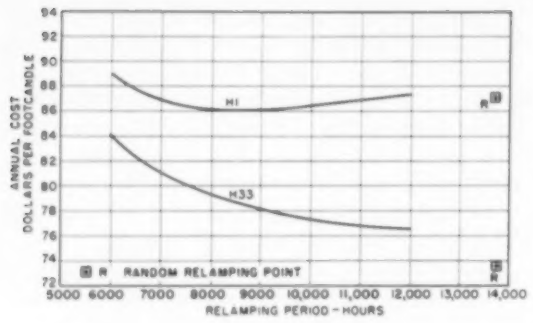
The authors do not claim that the figures given in these tables are typical for all installations, however, they do believe that these values have a relative significance that would apply to most installations of the type noted.

Group Relamping

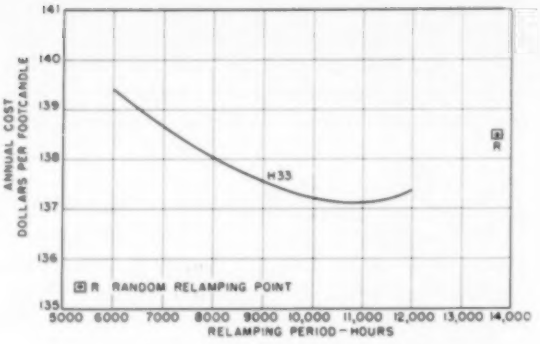
Group relamping of mercury lamps has generally been recommended as a sensible practice for good lighting maintenance. Previously it was thought that, for most typical applications, the best time to do this would be between 6000 and 8000 hours.[6] With the new H33 mercury lamps the group relamping cycle should be lengthened, to as much as 8000-10000 hours for street lighting installations, and even longer for some industrial installations. In fact, unless there are high cost factors, such as high labor cost to replace individual burned out lamps, there will be some industrial installations that will find that group relamping is not as economical with the new lamps as allowing them to burn out would be. This would be true also of street lighting if the investment cost has been

TABLE IV—Cost of Lighting Analysis for One Mile of Roadway. 60 feet wide with 1.:59 to 1.8 footcandles average maintained illumination. 240-volt multiple underground circuit. Power, 1¢/kwhr. $5.00 labor cost to replace one lamp at random, cleaning cost $2.00 per luminaire, 2 cleanings per year of 4000 burning hours.

	1	2	3	4	5
1. Type of lamp	Incandescent	Mercury	Mercury	Fluorescent	Fluorescent
2. Lamp description	860-watt PS52	400-watt H1LS	400-watt H33-1CD	1500 ma F72T12 cool white, extra high-output 4-lamp,	800 ma F72T12 cool white high-output 4-lamp,
3. Type of luminaire	Pendant	Oval	Oval	6-foot	6-foot
4. Number of lamps per luminaire	1	1	1	4	4
5. Rated initial lamp lumens per luminaire	15,200	21,000	20,500	37,600	21,200
6. Lamp life	3000	13,700	13,700	7500	11,000
7. Watts per luminaire (including auxiliary)	880	504	504	770	550
8. Coefficient of utilization	.374	.555	.555	340	370
9. Maintenance factor	.828	.648	.801	.675	.756
10. Number of luminaires	121	67	61	66	96
11. Average footcandles maintained	1.8	1.59	1.77	1.8	1.8
12. Net luminaire cost (ea.)	$186	$281	$281	$405	$363
13. Net additional accessory cost per luminaire	$77	$69	$77	$67	$53
14. Estimated wiring & installation cost per luminaire	$93	$123	$138	$106	$95
15. Net initial lamp cost each (list less 30% plus tax)	$2.87	$15.23	$17.50	$4.17	$2.70
16. Total initial cost less lamps	$43,076	$31,691	$30,256	$38,148	$49,056
17. Annual fixed charges (15% of above)	6,461.40	$4,753.65	$4,538.40	$5,722.20	$7,358.84
18. Total annual maintenance labor cost	$1,290.65	$365.80	$329.05	$975.50	$1,082.00
19. Total annual maintenance cost	$1,969.05	$935.01	$943.72	$1,950.37	$1,949.79
20. Annual energy cost	$4,259.20	$1,351.00	$1,230.00	$2,032.80	$2,112.00
21. Total annual operating cost	$6,228.25	$2,286.01	$2,173.72	$3,983.17	$4,061.79
22. Total annual cost	$12,689.65	$7,039.66	$6,712.12	$9,705.37	$11,420.63
23. Annual cost per footcandle	$7,049.81	$4,427.46	$3,792.16	$5,391.87	$6,344.79
24. Relative annual cost per footcandle	186%	116.7%	100%	144.5%	167%



(a)



(b)

Figure 13. Industrial installation group and random relamping cost comparisons. New H33 lamps are more economical to use than H1 types. (a) For typical conditions, H1 lamps should be group relamped at approximately 8500 hours and H33 lamps at 12,000 hours. Point R shows cost of random relamping which occurs at 13,700 hours (50 per cent on mortality curve, Fig. 10). Although it is slightly more economical to follow random relamping with H33 lamps in this case, group relamping is recommended as best practice (see text). (b) Where cost of lamp replacement labor, overhead or power rates are high, group relamping is more economical (see Table V). In this case, group relamping should be scheduled for approximately 10,500 hours.

written off completely. High investment cost tends to favor group relamping on the basis that investment is wasted if adequate light is not obtained for the money spent. Figs. 13 and 14 show some typical comparisons of cost of group relamping with mercury lamps of the two designs. Tables V and VI give some of the statistical material which entered into the curves.

In addition to strictly economic considerations, there are intangible benefits which will influence decisions as to whether or not to group relamp.[6] These always favor planned relamping:

(1) Improved seeing conditions resulting in: Fewer accidents, higher productivity, less spoilage and defects in workmanship, better worker morale.

(2) Value of good impression created by uniform appearance.

(3) Fewer interruptions in work by employees, supervisors, etc., to: investigate to see if lamp is *really* out, put through request for replacement, and handle request; and less time lost by those working under lamps being replaced and by curious and helpful "neighbors."

(4) Less time lost by idle machines.

(5) Lower cost of maintaining auxiliary equipment.

In the interest of good lighting maintenance, which nearly everyone recognizes as being desirable, it is recommended that mercury lamp fixtures be

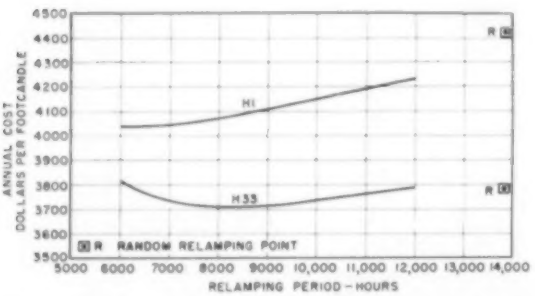


Figure 14. Street lighting group and random relamping cost comparisons. For assumed conditions, H1 lamps should be group relamped at approximately 6000 hours and H33 lamps at 8500 hours. New H33 lamps are more economical to use than H1 types. Group relamping saves money as compared to random relamping for conditions assumed (see Table VI).

TABLE V—Industrial Installation Group and Random Relamping Cost Factors (refer to Fig. 13).

	Condition A	Condition B
Annual fixed charges	$1,384.20	$2,700.00
Labor to replace 1 lamp		
Group relamped	.50	1.00
Random relamped	2.50	10.00
Power per kwhr	$ .01	$ .02

(See Table III for description of area and other pertinent data.)

TABLE VI — Street Lighting Installation Group and Relamping Cost Factors (refer to Fig. 14).

	HILS	H33-1CD
*Annual fixed charges	$4,753.65	$4,538.40
Labor to replace 1 lamp		
Group relamped	1.00	1.00
Random relamped	5.00	5.00
Power per kwhr	$ .01	$ .01

*—Fixed charges are itemized in Table IV.

There is a difference between lamp types in this respect because fewer H33-1CD lamps were used. H1LS lamps were spaced 79 feet apart while H33-1CD lamps were 86 feet apart, both staggered. Assumption was made that costs of one mile of cable, labor for handling the cable, and the share of distribution equipment costs and any other back-up expenses—a portion of which would apply to each luminaire—were the same per mile. Thus items 13 and 14 of Table IV show higher costs per luminaire for the H33 lamps. (See Table IV for additional data.)

cleaned at regular intervals and that the bulbs be wiped off carefully. Ordinarily this would be done during group relamping. If group relamping is not practiced, luminaires and bulbs should still be cleaned, and at this time the maintenance man should examine the base of the lamp to see how long it has operated. He can determine this readily from the markings of the digits on the base. If the lamp has burned three years or more in an industrial installation, it should certainly be removed. For easy calculation purposes, the authors are assuming approximately 4000 hours per year of operation both in street lighting and in industry. This of course varies considerably for industrial applications. In general, the authors recommend that anyone who has a mercury lamp installation prepare an IES cost of light calculation sheet for the particular factors that apply for his installation, thus determining whether or not in his case it would be desirable to group relamp or to follow some other system of good lighting practice.

The method of analysis used in the previous paper[6] is also recommended. This introduced the concepts of wasted energy and wasted investment as costs to be reckoned with, and showed how numerous cost variables caused the optimum point of group relamping to shift, not always coinciding with minimum cost of light. For simplicity the authors have used the more familiar "cost of light" method in the present paper, because it is more easily understood.

Ballast and Circuit Design

Several companies have already brought out special ballasts to operate the H33 mercury lamps. These ballasts will not start regular H1 lamps successfully at as low a temperature, but they will start them satisfactorily at some higher temperature. Ballasts that will operate both types are being labelled H33-1, and the differences in starting temperatures for the normal open circuit voltage are of course specified for both H33 and H1 lamps. Lamps of the new design are being etched H33-1 since they can always be operated on either the new H33 or old H1 ballasts.

Since the H33 ballasts do not have to have as much open-circuit voltage, their size and weight can be smaller in comparison with regular H1 ballasts. For example, one new ballast having 240 volts open circuit weighs 8 pounds less, a 20 per cent reduction, compared to a 300-volt ballast. It costs 45 per cent less than the heavier ballast. The cost calculations of this paper did not take such a saving into consideration.

Because of the easier starting characteristics of H33 mercury lamps, it is possible to load series

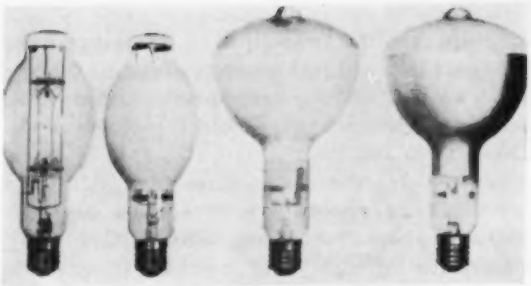


Figure 15. 400-watt H33 mercury lamps of improved design. Left to right: H33-1CD (E-H1-LG), H33-1GL/C, W or X, H33-1DN/C, W or X, H33-1FY or HS.

circuits, either of the straight series (ballastless) variety or those with series isolating transformers, to a higher degree than was heretofore practical. Depending on minimum starting temperatures and circuit factors, this may amount to an increase of over 6 per cent in the number of lamps that can be started and operated from a given size constant current regulator.

Fixtures

In the street lighting field special fixtures have been introduced which combine the ballast and fixture into one housing. This greatly reduces the combined costs of these items since the ballast will no longer require a special weatherproof casing. The introduction of the smaller and lighter-weight H33 ballast makes such built-in ballast design more attractive than ever, and it is expected that the tendency toward introduction of such fixtures will grow steadily. In many cases, fixtures with built-in ballasts will enable the use of choke ballasts to operate from 220 to 240 volts. This would permit operation of the new lamps down to fairly low starting temperature values. It would also further reduce the cost of the initial equipment.

Types of Lamps Available

At the time this paper is written the types of new improved-design mercury lamps commercially available consist principally of the 400-watt H33 group. Fig. 15 shows these lamps with their new ASA designations and corresponding designations under the system previously used. Included in this group are the semi-reflector and reflector types. It will be noted that the group contains lamps made with various colors such as the new high-output white, which gives roughly 10 per cent more lumens than do clear lamps, and the deluxe white lamps which give by far the best color of any mercury lamps, with approximately 75 per cent of the lumen output of the clear lamps.

Under active investigation for future availability

with improved design, including the new electrode structure, are the 700-watt H18 lamp types, the 1000-watt H12 and H15 groups and the H24 lamps which are designed for straight series operation on 6.6-ampere circuits. Other lamp types such as the 250-watt H5 and the 175-watt H22 are also being considered for the new construction. All these new types are expected to have the same improved lumen maintenance characteristics that have marked the introduction of the H33 variety. It is also expected that they will have the improved easier cold weather starting characteristics of the present types.

Increased Application Probabilities For Mercury Lamps

The extremely favorable combination of mortality and lumen maintenance characteristics of the new H33 lamp types makes it likely that they will be widely used. Mercury lamps have always been popular both for industrial and street lighting applications, but recently certain high output and super high output fluorescent lamps have threatened to take their place. With the development of the new lamps, however, it is apparent that the lowest cost of light is to be obtained with these new mercury lamps. This alone is enough to warrant their continued and increased use. It may also be that there will be a continuation of the trend toward mixing mercury lamps with fluorescent types. The two light sources seem ideally suited to blend together in many industrial installations. In some cases, mercury lamps are used at a higher mounting height with some fluorescent lamps at lower mountings. The advantage of mixing in a small percentage of fluorescent lamps for the mercury lamp installation is that in the event of power failure the fluorescent lamps will relight instantly while the mercury lamps require a few minutes to cool down and restrike their arc.

In the street lighting field, the new lamps increase the economic advantage of mercury lamps over any other type. They make for a much more desirable installation because there will be less variation between individual lamps and much less depreciation of light on the roadways. In addition, on series circuits it is now possible, using the new lamps, to place more units on a given constant current regulator circuit. And there is also the development of improved protective relays which, in themselves, permit much greater loading of the series circuits. We should expect to see a much greater conversion of existing series circuit lighting from incandescent to mercury and an extension of series lighting wherever cities and towns would like to take advantage of the economy of this system of operating mercury lamps.

In commercial and other non-industrial, non-street lighting applications, there will probably be a greater use of mercury lamps of either standard white (Type C phosphor) or deluxe white (Type X). Both types have seen increasing use in large high-ceilinged areas such as libraries, gymnasiums, sports arenas, waiting rooms, banks and even offices. The effect of the improvement in lumen maintenance of the new design will be to make these lamps more strongly competitive with other light sources at lower mounting heights. "Deluxe" mercury types made by the manufacturer responsible for their introduction have been converted to the new design (H33, etc.) wherever possible.

The authors wish to express their appreciation to the many persons who have assisted in the preparation of this paper, and particularly to our colleagues, R. A. Peterson, J. C. Hoffman, H. D. Fraser, and F. Rokosz.

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DISCUSSION

E. E. PARKS:* In our design calculations for lighting using the H1 mercury lamp, we used 16,000 as the average lumen output for this lamp. To maintain this average, it was necessary to replace the lamps when their output had depreciated to 12,000 lumens.

Beginning in 1954, we started testing these lamps and after two years our tests indicated that this point was reached after approximately 7500 hours of use. The rate of depreciation seemed to follow a straight line from 0 to 8000 hours, the limit of our tests.

We have been group replacing these lamps for nearly four years and our records have convinced us that the spot replacements average less than five per cent per year. Our tests show that the rate of depreciation is considerably faster and that the mortality rate is slower than that shown by the authors in their curves.

We started using the new H33 mercury lamp just one

*Nashville Electric Service Co., Nashville, Tenn.

year ago and have some 1700 in use. Plans call for group replacement of the new lamps after 9000 hours. In spite of the higher cost of the H33 lamp, our annual lamp renewal cost will be reduced by over $2500. Using data furnished to us by the lamp companies, we estimate that the lighting on all streets where mercury is used will be increased by some 16 per cent. The value of this added light to our customers, based on present bills, amounts to more than $17,000 annually.

Another significant improvement will be obtained by the reduction of the high to low ratio of illumination on the streets. With the H1 lamp, the ratio was 100 to 60 but with the new lamp it will be 100 to 80.

The development of the H33 mercury lamp is certainly an outstanding contribution to better street lighting and, as the authors stated, will increase greatly the possible applications using mercury lamps.

R. R. Wylie:* The authors have presented a very adequate review of the recent progress in mercury lamp development, omitting only the recent advances in strengthening of the arc tube support harness whereby the lamp construction was made sufficiently rugged to withstand extreme vibratory and shock operating conditions.

It has been our observation that unless extreme manufacturing care is taken, short circuited starting electrodes can occur more readily with the full press seal arc tube when burned base down. The use of a baffle, as described in the paper, or the use of H33 type of electrodes will reduce this tendency. Our experience has shown that the maintenance and mortality characteristic of the formerly used technique of "necking down," the arc tube produced as satisfactory a lamp without the hazard of "shortening" under certain operating conditions. We have not been able to confirm the authors' assertion that the cooling down or restrike time of the newer construction is improved over the older technique.

The introduction of the date recording base is most certainly a customer benefit. Significant savings in costly record keeping have been realized by all users. Further improvements in accuracy of timing of burning hours by means of date coding bases are anticipated.

Carefully kept records of roadway lighting users, who have installed hard glass outer envelope lamps instead of soft or lime glass envelope lamps, conclusively prove that significant improvements in the life and maintenance characteristics have been realized. This may be ascribed to the inherent differences in processing techniques of the two general types.

The maintenance data which the authors have presented on the H33 *vs* the H1 is particularly interesting when compared to data submitted in other 1959 IES Conference papers. Are the H1 data based on lamps burned base up, base down, or a mixture of these burning positions? Are the data based on lime glass or hard glass outer envelope lamps, or a mixture of these?

In typical economic studies we invariably find general agreement with the authors' calculations. It should be emphasized that the authors' findings are extremely conservative. The use of the higher lumen output mercury lamps using the orthophosphate color modifying phosphor in appropriate equipment will give further tremendous advantages costwise to the mercury lamp user. He can also anticipate the added bonus of good color rendition, much improved over the clear lamps studied.

*Sylvania Electric Products Inc., Salem, Mass.

E. C. Martt and R. D. Churchill:* Since the description of the new electrode and related performance are presented in the Martt, Green, Gottschalk paper,[1] no further comment need be made here. The full-diameter pinch seal and the simplified mount structure have both been in use now for several years. We made a further improvement over the mount described by silvering support wires which increase lead reflectivity and lumen output, particularly in phosphor-coated lamps.

The small resistor has the advantage described of lower cost, and welding problems, though minor, are reduced. However, we find that it will not withstand as high a voltage as the wire-wound, nor as high as other types which are smaller than the wire-wound. This is important in hot restarts when nearly full open circuit voltage appears across the resistor. If the heat-dissipation capacity of the resistor is too low, it will fail under such conditions.

Our experience and studies confirm the basic cause of mercury shorting as described in the paper. We find that this problem can be greatly reduced by proper placement of thorium in the electrode. Our data also show that the new oxide electrode does not cause mercury shorting when burned in the base-down position. Our tests on 400-watt lamps to several thousand hours confirm this.

We find that properly treated lime glass outer envelopes are satisfactory to longer life than the 6000- to 10,000-hour period discussed, and there is no need to group-replace lamps for that reason. Lamps are regularly burned to 12,000 hours in our test racks with no sign of crazing, and field reports indicate that in actual installations lamps are operating satisfactorily for even longer periods.

Our laboratory tests and field experience to date show that life of the new lamp is as good as the one with thorium electrodes. Neither of these lamps fail (to 12,000 hours at least) due to electrode failure, and for this reason we would expect the mortality curves to be about the same. While field data are important and valuable, we question whether this information is complete and accurate enough to justify the revised curve in Fig. 10.

It is encouraging to see the industrial cost of light data presented in the form which is growing in use and, as the authors state, is easily understood.

While the over-all industrial cost of light results presented in the paper agree with our studies, the curve for the H1 lamp in Fig. 13a shows a somewhat longer relamping period for minimum cost than does our work. Also, Fig. 13a shows less of a difference between minimum group relamping cost and spot relamping cost than do our studies. Since lighting system maintenance has a major effect upon these data, could the authors provide more information on the breakdown between assumed lamp depreciation, luminaire depreciation, and room surface depreciation, over the range of relamping intervals from 6000 to 12,000 hours?

The figures in the street lighting cost analysis are, in general, consistent with data previously presented. The cost of the fluorescent high output system is based, however, on 800-ma operation. In street lighting service, it is standard practice to operate the high-output lamp at 1000 ma. While the cost analysis based on 800-ma operation penalizes the high-output system, it does not, in this case, change the relative over-all picture.

The results of our cost studies with regard to group relamping of the H33-1 type lamp in street lighting service, show minor differences from the data presented in Fig. 14, probably due to differences in assumed installation costs. Our calculations show minimum cost of light with group

*General Electric Co., Cleveland, Ohio.

relamping occurring at approximately 10,000 hours. Our studies also show the minimum group relamping cost of light to be about the same as the cost of light for spot relamping. A variation of from $1.50 to $10.00 in spot relamping truck and time charges, varied the cost of light only about one half of one per cent.

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FRANCIS CLARK:* The factors mentioned by the authors do favor group relamping, but it does not seem that this should be influenced by luminaire investment, whether or not it is written off. Investment is made for return, not a financial one, in this case, but light, all that luminaires are expected to produce. Light, in turn, influences seeing, safety, comfort, production, selling, and so on—factors of ever continuing importance.

Regardless of mathematical amortization, luminaires should yield the designed amount of light as long as possible. Lamps should be removed when they have depreciated to some predetermined percentage of initial lumen output. Even with the excellent lumen maintenance curve of H33 type lamps, it seems that the extremely long life of many mercury lamps will require them to be removed quite some time before burnout.

Cleaning luminaires and lamps is important for maintaining light. It costs almost nothing to change lamps during cleaning, so group relamping should still be considered strongly, even for the newly designed mercury lamps.

Planning economic cleaning cycles with group lamp changing cycles requires knowledge of specific rates of dirt accumulation as well as lamp depreciation and life. It is important to clean when needed, not too early, or too late. Timing of lamp removal is just as important. A lamp should not be removed too soon—while lumen output is adequate and many burning hours, at high output, are left. It should not be removed too late—after it has burned out and caused annoyance, loss of light, and the cost of interim replacement, or when it has become so reduced in output that it is not worth the electricity to burn it.

From these statements, and the fact that improvements in mercury design have come so fast, it is important to know how realistic the stated 9000-hour economic life ratings actually are. If they are too optimistic, we will be removing lamps too late. If they are pessimistic, we will be changing them too soon. In either case, we are defeating the effort to provide high lighting levels, economically.

W. S. TILL AND M. C. UNGLERT:** The authors appreciate the constructive comments of the discussers and wish to thank them for their interest in the paper.

Mr. Parks' calculations of reduced costs, higher maintained illumination and more uniform lighting with the new H33 mercury lamps bear out the conclusions expressed in the last section of the paper. The specific savings to be realized in Nashville will certainly be of interest to others responsible for providing good street lighting.

In regard to mortality, Mr. Parks indicated that spot replacements averaged less than five per cent per year. This agrees closely with the upper curve of Fig. 10, data for which were obtained elsewhere. In using the lower curve for calculations, we have obviously been conservative.

Mr. Wylie suggests that the paper might have included a description of a means of strengthening the arc tube supporting framework. Our contention is that the construction described needs no further strengthening. Adding unnecessary parts sometimes does more harm than good.

As to the matter of short-circuited starting electrodes, our tests of large numbers of lamps of both full press seal and smaller seal structure has shown that each type is reliable when properly made.

Regarding faster warm-up time for lamps of new construction, a statement to that effect was included in the draft of the paper submitted to the Papers Committee, however, that section was deleted in the interests of shortening the paper and does not appear in the published version. Warm-up and restrike time are so much dependent on the ballast and fixture designs, as well as on lamp design and ambient temperature, that comparative figures normally taken for bare lamps in laboratory tests are not a very practical guide to the user. We claim only that there has been a very slight reduction in the relative warm-up time through recent years.

Lumen maintenance data for H33 *vs* H1 lamps were based on mixed horizontal and vertical operation. Both the H33 and H1 lamps used in the tests were, for the most part, made with soft glass envelopes, as a control measure. (Regular H33 lamps are made only with hard glass outer bulbs.) We do not ascribe any of the improvement in lumen maintenance of H33 lamps, as compared with H1, to the use of hard glass or a particular burning position.

Messrs. Martt and Churchill questioned the merit of the small resistor in respect to hot restarts. Our tests and those of the Osram Co. in Germany show that it increases in resistance when excessive voltage is applied and maintained, as under conditions of hot restarts. This acts to reduce current and resulting heat. Lamps made with the small resistor meet or exceed the American Standards Association's requirements for flashover protection.

As to preventing mercury shorting in arc tubes containing thorium electrodes, there is not much freedom of choice in positioning the thorium because the entire electrode assembly is of such small size. We have found the use of the quartz bead a positive way to prevent this occurrence. The use of two starting electrodes, both electrically connected, is an acceptable substitute that has been used in the 100-watt lamp where lack of space prevents the use of the bead.

Regarding the crazing of lime glass, we agree that under the controlled conditions of life test racks lamps up to 425 watts in size are satisfactory to 12,000 hours and beyond, but we point out that the ability of lime glass to withstand crazing depends on several factors other than time, *e.g.*, bulb temperature, rate of air movement past the bulb and concentration of sulphur dioxide or other common atmospheric contaminants. These factors vary widely in industrial applications. For this reason and to retain an ample safety factor, we recommend relamping for the range of 6000-10,000 hours. This does not mean that lamps with lime glass bulbs cannot be used beyond 12,000 hours in most ordinary circumstances, but how long can they be used in *all* circumstances? Of interest in this connection is the fact that, to our knowledge, no U. S. manufacturer now uses lime glass for 700-watt and 1000-watt mercury lamps. Lime glass was formerly used for these sizes, but was found to have inadequate margin of safety against atmospheric corrosion. This serves to point out that the crazing of lime glass is a very real thing and that it should be considered in the choice of a mercury lamp for industrial application. The section of the paper in which this problem was discussed explains why the new H33 and related lamps of im-

*Lighting Services, Inc., Waterbury, Conn.
**Authors.

TABLE A.

Lamp	Burning Time (Hours)	Lumen Factor (1)	× Dirt Factor (2) =	Over-all Maintenance Factor
		For Random Relamping		
H1-LS (E-H1)	13,700	.72	.88	.634
H33-1-CD (E-H1-LG)	13,700	.89	.88	.783
		For Group Relamping		
H1-LS	6,000	.845	.88	.744
H33-1-CD	6,000	.953	.88	.839
H1-LS	8,000	.817	.88	.72
H33-1-CD	8,000	.941	.88	.828
H1-LS	10,000	.788	.88	.693
H33-1-CD	10,000	.930	.88	.818
H1-LS	12,000	.772	.88	.679
H33-1-CD	12,000	.921	.88	.810

(1) Lumen factor for random relamping is average percentage of initial lumens produced from zero through 13,700 hours. Lumen factor for group intervals considers also the effect of interim replacements on total light output through the chosen cycle.
(2) Dirt factor of .88 assumes a relatively clean area with luminaires washed every 2000 hours.
No additional factor was used for room surface depreciation because the area chosen was a type A room. Detailed step-by-step calculations are available in pencil form and photocopies could be supplied if requested.

proved lumen maintenance are made only with hard glass.

Concerning Fig. 10, the mortality curves shown are conservative. Mr. Parks' comments serve to strengthen this point since, as we have already mentioned, data from his installations were not included in these curves.

In making the group *vs* random relamping cost studies, mercury lamp lumen maintenance was determined from Fig. 7 as a percentage of original output. Similarly, a dirt factor was selected for each burning interval. The product of these two became the maintenance factor in each case. Examples of actual values used are shown in Table A.

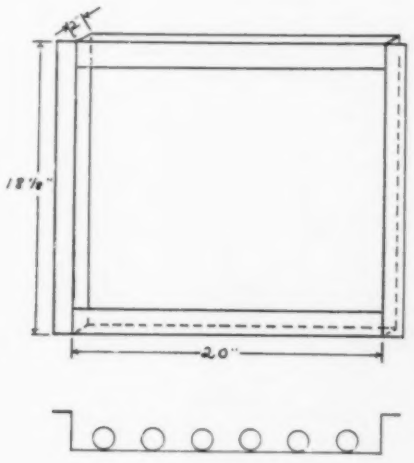
Mr. Clark stated that systematic group relamping is highly desirable, regardless of the status of equipment amortization, which has a large effect on annual cost of light (see Figs. 11 and 12). In answer to his question as to how realistic the 9000-hour economic life rating is for the new H33 lamps, we point out that Figs. 13 and 14 show that most economic lives vary widely according to cost factors prevailing in the installation. For street lighting, 8000-10,000 hours is about right, while for industrial lighting, the cycle should run between 10,000 and 13,000 hours. These figures are based on the published mortality and lumen maintenance curves and other bases given in the paper. Since lamp improvements have been occurring rather rapidly, these figures may soon be found to be quite conservative. In any case, the user is urged to make his own cost study. In doing so he should not limit himself to life ratings published by the manufacturer, but should be guided by either published curves or similar data which he may have established through his own test or operational records.

Lighting for Transparent Photographs

Uniform illumination for 16- by 20-inch transparent photographs, exhibited in a display case with only a 2½-inch deep cavity for housing lighting equipment, is provided by a custom-made illuminator of sheet aluminum housing six F15T8 warm white fluorescent lamps. Lamps are mounted near the back of the unit, with a .020-inch Plexiglas diffuser placed between lamps and transparency. Uniform distribution of light is obtained through the positioning of lamps, use of a diffusing panel behind lamps and the diffuser placed between lamps and transparency. A spring tension wire extended across the lamps prevents them from dislodging during shipment.

Since remote ballasts are used in the installation, a multiconductor cable with locking male and female connector, for ease in installation, was installed between the components.

The illuminator, used in a National Bureau of Standards traveling display, was designed by Norman C. Winchester, Lumilight Co., Boulder, Colo., and entered in the Rocky Mountain Section's 1959 My Most Interesting Lighting Job competition.



Design Factors of Extra-High-Output Fluorescent Circular Cross-Section Lamps

By C. J. BERNIER

During the past few years, heavily loaded fluorescent lamps have become increasingly important for indoor and outdoor applications. Fluorescent floodlighting and street lighting have become more acceptable with the advent of smaller and lighter luminaires. Circular cross-section T12 lamps used in these applications are most satisfactory. The lamps may be used in luminaires employing reflectors originally developed around the T12 bulb. In installations where it is desirable to project a light pattern to maximum distances, the high ratio of lumens per foot and uniform source brightness of the T12 has given more light, where needed, and at lower cost. This paper discusses problems involved in meeting the demand for uniform cylindrical sources at loadings of 25 watts per foot and above.

Ultraviolet radiation produced in the positive column of a fluorescent lamps is a result of collisions between high "temperature" electrons and mercury atoms. These electrons acquire their velocities from the acceleration by the axial field of the column and their velocity distribution is Maxwellian. The higher the electron temperature the higher the average energy of the electrons and therefore, the greater the percentage of electrons having sufficient energy to excite mercury to the 2537A resonance radiation level. If the mercury vapor pressure is kept constant at its optimum value by some means[1] and the electron density is increased, by increasing the current, the amount of 2537A radiation produced approaches a "saturation" value. Fig. 1 shows the behavior of a T12 lamp, filled with argon, as the power input to the arc is increased by increasing the current while the mercury temperature is maintained at 40C by controlled cooling. The reasons for constantly reducing slope (efficiency) of the light *vs* watts curve have been explained in some detail[2] in a paper by Waymouth, Bitter and Lowry. Briefly, when the time elapsed between an exciting collision and a de-exciting collision (so-called "collisions of the second kind") is short, the density of excited atoms becomes independent of the electron density and so does the radiation output. Consequently, in order to increase the radiation output at higher loadings the electron temperature must be increased. Also, since the cathode and anode voltage drop in the lamp is relatively constant, increasing the current also increases these electrode losses. Consequently, in order to maintain good efficiency at higher and higher loadings, the lamp current must be kept as low as possible.

One way to increase electron temperature is to increase the mercury ion mobility. The mobility of mercury ions is greatest in helium and decreases with increasing atomic weight through the rare gases. The electron temperature can be increased, therefore, by using neon or helium, or partial pressures thereof, instead of pure argon as a fill gas. Lamps with high light output can be made at substantially higher efficiency than with argon-filled lamps as long as the increased saturation value is not offset by increased losses due to elastic collisions between electron and rare gas atoms. Fig. 2 shows curves of light output per watt *vs* positive column watts for the 48-inch T12 lamp at 40C mercury temperature using approximately 2 mm pressure of various gases. At loadings of about 25 watts per foot and above, it is seen that neon becomes more efficient than argon as a fill gas. The curve for helium does not appear in this figure but it crosses the curve for neon at some higher level of loading. Thus a whole new area is available for higher and higher loading of the T12 bulb at good efficiencies.

The use of neon or helium as a fill gas also reduces the magnitude of the current required to operate the lamp at a given loading. Since the mercury mobility is increased, the ion current to the wall is increased, and the field must increase in order to maintain equilibrium conditions. This means that the power loss at the electrode is reduced by a certain amount and that amount is put back into the positive column where it can produce more light. In addition, the ballast cost is reduced and the over-all efficiency of the circuit is improved.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif. Author: Sylvania Lighting Products, a division of Sylvania Electric Products Inc., Danvers, Mass. Accepted by the Papers Committee as a Transaction of the IES.

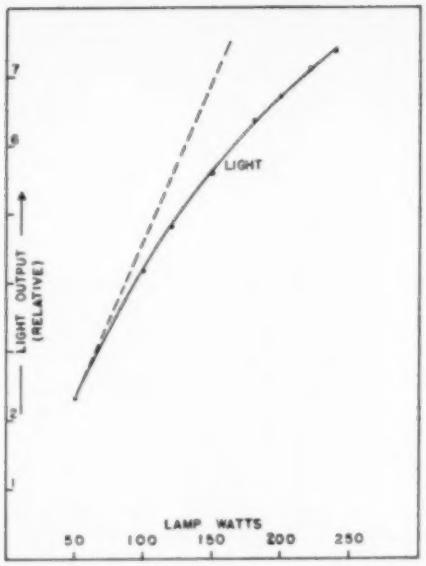


Figure 1. Light output vs power input for 96T12 lamps filled with argon at 1.2 mm. Mercury temperature is constant at 40C. (Dashed line indicates the locus of a point of constant efficiency.)

Gas Mixtures

The 25-watts-per-foot T12 lamp now on the market represents the first step in the direction of loadings so high that the use of neon and helium as the principal fill gas will increase considerably. For the relatively low loadings of 25 watts per foot, mixtures of argon-neon and argon-helium have been used.

Fig. 3 gives the light output and current at 100 watts for the T12 48-inch lamp as a function of the neon concentration in argon at 1.0 mm pressure. The curves show that for a given current such as the 1.5-ampere now used for extra-high-output lamps, the specified lamp loading of 25 watts per foot can be achieved by selecting the proper gas mixture and the efficiency will be as good or better than that of an all argon lamp which could not be loaded to 25 watts per foot at 1.5 amperes in the first place.

If helium is added to the argon fill gas, the light output falls off somewhat more rapidly than in the case for neon. The collision cross-section for elastic collisions between electrons and gas atoms is greater for helium than for neon. However, the current required for a given wattage decreases much more rapidly for additions of helium, as shown in Fig. 4. For the loading of 25 watts per foot, a very small concentration of helium is required.

Fig. 5 shows the parameters for an eight-foot T12 lamp designed to operate at 1.5 amperes and loaded at 25 watts per foot. The lamp uses approximately 10 per cent helium in the fill gas and has a pressure of 1.0-1.2 mm. Here it is shown that with 10 per cent helium a lamp with a loading of 25 watts per foot is obtained at a current of 1.5 amperes at better efficiency than that of an all argon lamp. The reasons for the use of the helium-argon mixture in the present extra-high-output T12 lamps are discussed below.

Lamp Performance

In designing a lamp for heavy loadings, two important factors must be considered—rated life and lumen maintenance. One function that the rare gas performs in the lamp is the protection of the cathode emissive material from evaporation. At a given pressure, the cathode material in a lamp using the heavier argon as a principal gas will experience a slower evaporation rate than that in one using neon as a principal gas. Electrode structures[3] have been designed and used, in the 25-watts-per-foot neon-argon lamp, which perform satisfactorily on the normal rapid start circuit for approximately 5000 hours. However, the rated life of the extra-high-output lamp has recently been increased to 7500 hours. This increased average burning time is easily achieved with argon-helium filled lamps.

The ability of a fluorescent lamp to maintain brightness with burning time is a complicated function of many variables. Of paramount importance are the electron temperature and the ion and electron current to the phosphor coating on the inside of the bulb surface. In general, the higher the incident energy on a given section of phosphor coating, the poorer the maintenance. It follows, then, that for uniform maintenance of surface brightness the fluorescent surface must be uniformly loaded.

Fig. 6 shows the lumen maintenance for T12 lamps using argon-neon and argon-helium gas mixtures at loadings of 25 watts per foot and 50 watts

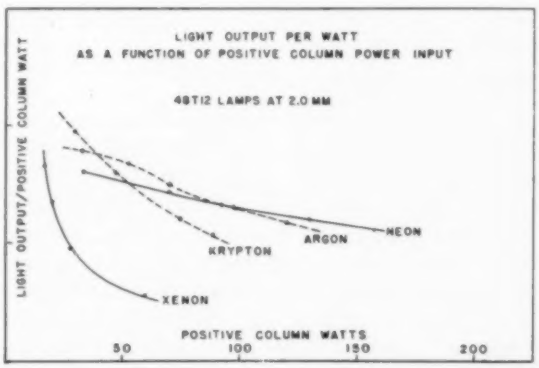


Figure 2. Light output per watt vs positive column power input for 48T12 lamps filled at 2.0-mm pressure with various gases.

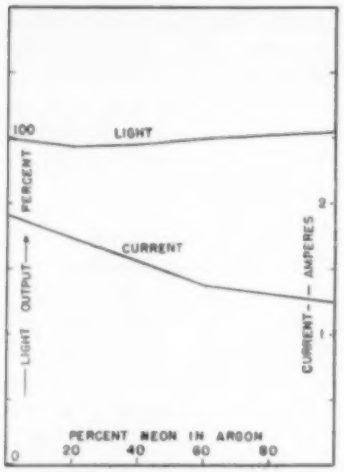


Figure 3. Light output and current (for 100 watts) as a function of neon concentration in argon at 1.0-mm pressure for the 48T12 lamp.

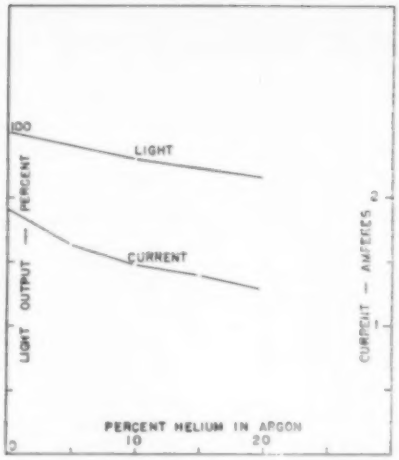


Figure 4. Light output and current (for 100 watts) as a function of helium concentration in argon at 1.0-mm pressure for the 48T12 lamp.

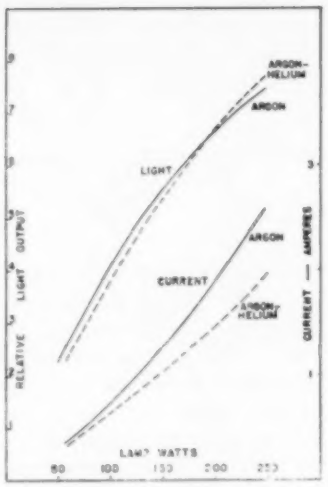


Figure 5. Light output and current rs lamp watts, 96T12 lamps at 1.2-mm pressure with argon, 10 per cent helium in argon. Mercury temperature constant at 40C.

per foot. The important figure considered in the design of lighting installations is "mean lumens," which is the average light output obtained from a lamp throughout its rated life. The curves show that at 25 watts per foot, for a rated life of 5000 hours, the choice of gas mix is a toss-up. However, with the new ratings of 7500 hours, the helium-argon lamp, although slightly less efficient at early life, gives a five per cent increase in "mean lumens." For heavier loadings, the advantage of helium-argon over neon-argon is even more pronounced, as shown in Fig. 6. The curves are for T12 lamps with a much larger concentration of helium in argon loaded to approximately 50 watts per foot and show a 12 per cent advantage in "mean lumens" for the helium-argon lamp for 5000-hour rated life. Helium-argon mixed gases are used in all 25 watts-per-foot T12 lamps being marketed at this time.

Controlled Lighting

Very high brightness fluorescent lamps of small diameter have made possible the design of luminaires which produce a controlled distribution of light. With reflectors of special design[4] more effective illumination can be achieved with a single lamp than with several lamps packed together. For these applications, where uniform surface brightness is essential, the circular cross-section lamp is most practical. For some applications, where it is desirable to direct all the light below a chosen cut-off plane, only a portion of the circumference of the source is utilized. Reflector-coated lamps are therefore used to produce brightness levels of 6400 footlamberts and up.

Some of the brightness levels obtained with lamps at various loadings are shown in Table I. Controlled fluorescent fixtures designed around the smooth T12 bulb of very high brightness are presently doing a remarkable job of lighting on highways, runways, service station areas, signs and building faces. The high brightness T12 lamp is also opening up a new era in the field of photocopying where accurate control of projected light

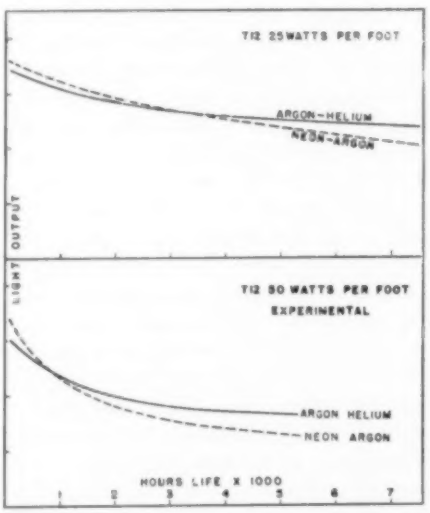


Figure 6. Lumen maintenance curves for T12 lamps filled with argon-helium and with neon-argon operated at loadings of 25 watts per foot and 50 watts per foot.

TABLE I.

Lamp	Loading (Watts per foot)	Surface Brightness (Footlamberts)
48T12 High-Output	15	3400
48T12 Extra-High-Output	25	5000
48T12 Extra-High-Output 135° Reflector Coated	25	6400
48T12 Extra-High-Output 235° Reflector Coated	25	8000
48T12 Experimental	50	9000

is essential. Lamps used in all these applications must furnish uniform brightness throughout life.

Conclusion

The high brightness fluorescent lamp of circular cross-section has become a popular light source for general lighting. At 25 watts per foot, the T12 lamp provides high efficiency (almost 70 lumens-per-watt for the 96T12 lamp), has long life (7500 hours) and furnishes 75 per cent of rated lumens at 5000 hours.

Very high brightness sources of exact dimensions are readily obtained by using the T12 bulb with internal reflector coatings. Such lamps are especially suited for controlled lighting applications where the important requirements are high brightness and uniformity of the source, not lumen output alone.

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1. Gungle, W. C., Waymouth, J. F., and Homer, H. H.: "Operating Parameters of High Output Fluorescent Lamps," ILLUMINATING ENGINEERING, Volume LII, No. 5, p. 262 (May 1957).
2. Waymouth, J. F., Bitter, F., and Lowry, E. F.: "Factors to be Considered in the Design of High-Output Fluorescent Lamps," ILLUMINATING ENGINEERING, Volume LII, No. 5, p. 257 (May 1957).
3. Bernier, C. J., and Gungle, W. C.: "Glow Discharge Characteristics of Fluorescent Lamps," ILLUMINATING ENGINEERING, Volume LIII, No. 1, p. 32 (January 1958).
4. Spencer, Domina Eberle: "Controlled Fluorescent Reflector Design for Sharp Cut-off and Uniform Distribution," ILLUMINATING ENGINEERING, Volume LIV, No. 3, p. 167 (March 1959).

DISCUSSION

H. A. ANDERSON:* We certainly appreciate the manner in which the author of this paper has outlined the advantages of extra-output fluorescent circular cross-section lamps. Examination of the data raises a few questions about which we would like to have further information:

(a) The paper states that, at 25 watts per foot, the 96T12 lamp provides 70 lumens per watt. We would like to know which fluorescent color is represented by this figure. Also, does this lumen rating include the gain resulting from the use of classified powder, as taught by Butler and Homer in their paper?[1] If not, can we assume such an improvement possible with these extra-high-output lamps?

(b) The author mentions the use of a titanium dioxide reflector coating for the purpose of improving the coefficient of utilization when used in street lighting or other types of outdoor fluorescent floodlighting luminaires. Although we realize the importance of this application, we feel that the fluorescent reflector T12 extra-high-output lamp would have even wider application for industrial lighting, especially at higher mounting heights. Better utilization and downlighting, as well as improved lighting maintenance, would result from a lessened effect of dirt and dust on reflector type lamps. This would be especially true in dusty industrial locations where fixtures are installed at high mountings and are difficult to clean periodically.

(c) We also raise the question of diffusion of gases when two or more rare gases are mixed in a fluorescent tube. Does the author have any data regarding the effect of uneven distribution of gases and possible effects on lamp stability? Also, we would like to know if there is any difference in such effects on neon-argon lamps as compared to helium-argon lamps?

We feel that the circular cross-section extra-high-output fluorescent lamps would also have an economic advantage in lamp making; more consistent control in uniformity and handling during processing could result in cost savings which are eventually passed on to the customer.

1. Butler, K. H. and Homer, H. H.: "Improvements in Fluorescent Lamp Efficiency From Particle Size Control of Phosphors," a paper presented at the National Technical Conference of the Illuminating Engineering Society, September 7-11, 1959, San Francisco, Calif.

E. LEMMERS:* The author has presented an interesting paper. This paper contains a brief but excellent résumé of the physics involved when the lighter rare gases such as neon and helium are used. The most important problem, when such gases are used, is adequate lamp life. All our tests have shown markedly longer life with argon than when neon, or a majority percentage of neon, is used as a fill gas. Our past discussions and the current paper support this view.

We agree with the statement that "lamps with high light output can be made at substantially higher luminous efficiency than with argon-filled lamps as long as the increased saturation value is not offset by increased losses due to elastic collisions between electrons and rare gas atoms." Our data at 25 watts per foot indicate elastic collision losses are always excessive with a major percentage of neon in an argon-neon mixture, or in argon with even a small percentage of helium added. For the 10 per cent to 20 per cent helium in argon mixture discussed in this paper, our tests at 25 watts per foot indicate a lumen-per-watt luminous efficiency 10 per cent to 20 per cent lower than for pure argon.

In each graph there is some information on which we are in general agreement. It appears in Figs. 1 to 5 that the data for mixed gas lamps were obtained at the mercury pressure that is expected at 40C (control area); however, the argon data do not seem to be under the same degree of control. This tends to show the argon-filled lamps as less favorable.

Fig. 1 shows a 96T12 argon lamp at 200 watts to have a luminous efficiency only 74 per cent of its 50-watt level. This value seems very low because in many tests under similar conditions we find values that average 88 per cent. Perhaps the author can explain the low value and tell us how mercury control was determined?

Figs. 3 and 4 show that about 1.9 amperes were needed with the control area at 40C to obtain 100 watts in an argon-filled 48T12 lamp. Our tests indicate that only 1.65 amperes are needed. Could the difference be due to lack of mercury pressure control?

Fig. 4 shows a reduction in both current and light output for a fixed wattage in a 48T12 lamp when helium is added to the argon. Fig. 5, for a 96T12 lamp, shows the expected difference in current for 10 per cent helium added to argon; however, the reduction of light output which must occur if Fig. 4 is acurate, does not appear. Our own studies show the relationship applies for 48-inch or 96-inch

*Duro-Test Corp., North Bergen, N. J.

*General Electric Co., Cleveland, Ohio.

lamps irrespective of the filling gas pressure difference noted between Figs. 4 and 5.

The paper indicates that the mixture of argon and helium has improved life and maintenance over neon-argon fillings. However, the use of such a lamp is pointed to special applications for which it is "especially suited," such as where high luminous efficiency is not of primary importance. We find that whenever helium is used in lamps at approximately 25 watts per foot, luminous efficiency is always lowered.

T. S. MADONIA:* A review of the development of fluorescent lamps reveals the significant trend to develop new sources to produce more light output per foot of lighted length, which simply means more economical systems to obtain desired lighting levels. The lighting industry has witnessed the development of 600-ma loading of slimline lamps, 1000-ma loading of rapid-start lamps and, most recently, 1500-ma loading of unique designs of rapid-start-type lamps.

The author has reported new techniques in improving the performance of the circular cross-section design of these 1500-ma loaded lamps. We are also pursuing this design because our studies reveal it to be the best approach from the standpoint of lamp performance and economics, luminaire design and maintenance.

The author reports that higher efficiencies can be obtained with a mixture of argon-helium as compared to argon. From their studies of gas mixtures Meister and Heine reported in their papers, "Low Pressure Mercury Discharges"[1] that a combination of gases may produce higher efficiencies than any single component alone. This principle has been proven to apply to extra highly loaded lamps as well. Our studies support the claims of the author for argon-helium mixtures and indicate that still higher efficiencies are possible with other mixtures. We also confirm that superior lumen maintenance is obtained with an argon-helium mixture.

The author has discussed the basic characteristic of lamp life as affected by gases lighter than argon. I would like to elaborate on this point. In the design of cathodes for these high loadings, two conditions must be considered: (a) the effect of cathode fall during operation and (b) the effect of the starting mechanism.

Our studies reveal that the cathode fall (as measured in accordance with a refinement of the techniques reported by Waymouth at the 13th M.I.T. Conference on Physical Electronics) of a lamp containing an argon-helium mixture is but slightly higher than that obtained in an argon-filled lamp. This means that no problem will be encountered in obtaining the same life with an argon-helium mixture as with argon.

However, the difference in cathode fall is only one factor affecting the life of the lamp. The effect of lamp starting is equally important, particularly with highly loaded lamps, regardless of the gases used. The cathode must be designed to minimize destruction during starting.

Our work in this field has resulted in new coil designs and emission materials to meet these two major requirements, resulting in the rating of 7500 hours at three hours per start for our high-output lamps.

We agree with the author that these new developments in gas mixture and cathode designs, coupled with the developments in phosphor processing which have increased the lumen ratings, have clearly defined the merits of the T12 circular cross-section approach to 1500-ma loading and point to a practical development of even higher loaded lamps in the future.

1. Meister, G. and Heine, T.: "Low Pressure Mercury Discharges," ILLUMINATING ENGINEERING, Vol. XLIV, No. 11, p. 681 (November 1949); Vol. XLVII, No. 3, p. 159 (March 1952) and No. 12, p. 660 (December 1952).

CARL J. BERNIER:* The rating of 70 lpw for the 96T12 lamp is for the cool white color. This rating does include some of the gains resulting from the use of phosphors processed by the Butler-Homer method, discussed in their paper. Further gains are, of course, being anticipated.

No adverse effects, either on light uniformity or lamp stability, from gas diffusion have been noted in the mixed gas lamps in the temperature range from −20F to 90F.

Some of the questions asked involve the validity of data taken when mercury temperature is so difficult to control. The data presented in Figs. 1 and 4 (40C, as mentioned in captions) were obtained with the use of a liquid bath in which the lamp is totally immersed. The liquid has high transparency, very low conductivity and is kept at exactly 40C. Light output is measured by a series of photocells inserted in the walls of the chamber and standard lamps are used for calibration. We feel that this method gives acceptable results since the stabilization time is very short and the slight reduction in bulb wall temperature has a negligible effect on lamp parameters.

The addition of 10 per cent helium to argon does reduce the positive column efficiency but at the same time it increases the saturation level of the discharge and reduces the electrode losses as power input to the lamp is increased. At some point, therefore, the efficiency curves must cross. Our tests show that the cross-over point occurs at a loading of slightly less than 25 watts per foot.

We are in agreement that the design of cathodes for lamps using mixed gases must take into consideration the effects of starting. The electrode structure, which includes cathode, anode and emission material, must be designed to minimize the tendency to instant start on rapid-start circuits in order to obtain full lamp life.

*Westinghouse Electric Corp., Bloomfield, N.J.

*Author.

IES Emblem

The IES official emblem is available to members in ½-inch, 14-karat gold, lapel screw-back buttons at $3.50 each. Background of emblem is blue for Members, red for Associates. Order from Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

A.I.A. File No. 31 f

INSTALLATION AT BUFFALO INCANDESCENT LIGHT CO., 201 GENESEE ST., BUFFALO, N. Y.

Lighting a Sidewalk and a Building Facade

LIGHTING OBJECTIVE: To provide a high level of illumination on a store's identification sign and on the sidewalk below.

GENERAL INFORMATION: This store front, which is 60 feet long and 20 feet high, is surfaced in matte aluminum (65 per cent RF). Red letters (12 per cent RF) are mounted against the facade at approximately 16 feet above the sidewalk (40 per cent RF).

INSTALLATION: Both sidewalk and facade illumination is from a continuous run of Revere Electric Mfg. Co. catalog No. 9800 coping lights mounted on the building 20 feet above the sidewalk. Units are equipped with plastic diffusers and two T-12 cool white 800-ma fluorescent lamps. Brightness of the facade (sign background) varies from 150 fL at the top of the sign letters to 4 fL at the bottom near the sidewalk. Sidewalk illumination varies as follows.

distance out from building in feet	fc	distance out from building in feet	fc
1	42	5	21
2	44	6	21
3	24	7	18
4	22	8	17

Lighting designed by Buffalo Incandescent Light Co., 201 Genesee St., Buffalo, N. Y.

Lighting data submitted by Niagara Mohawk Power Corp., Buffalo, N. Y. as an illustration of good lighting practice and to aid in the design of similar installations.

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A Study of Glare from Very Large Sources

By R. G. HOPKINSON
R. C. BRADLEY

The classical psychological concepts of "figure" and "ground" have hitherto formed the basis of all studies of visual discomfort due to glare. When the source is large, as in the case of a luminous ceiling or glass wall, it may itself play a significant part in determining the adaptation level because it occupies a large part of the field of view, and so the classical concept may not apply.

Studies are described of glare under conditions applicable in practice to very large illuminating sources. The evidence so far suggests that a luminous ceiling whose brightness exceeds about 150 footlamberts may cause visual discomfort to some people.

LIGHTING practice has undergone changes in recent years which have demanded a different way of thinking about the problem of visual discomfort. In both natural and artificial lighting the move has been away from small windows and small luminaires towards very large sources of light which themselves occupy a substantial part of the visual field.

Although large sources are often of much lower brightness than those they replace, complaints of glare or of discomfort in some form are still heard. This could be due to a general movement towards higher standards of comfort in all the things of life, and it could be due to real visual effects so far unsuspected.

At a symposium held at Cornell University in 1956 under the aegis of the Illuminating Engineering Research Institute, one of us (R. G. H.) discussed the present state of knowledge on visual comfort, and forecast some of the difficulties which would arise when classical concepts were applied to problems of visual comfort when very large sources provided the illumination of the visual field.[1] This problem was discussed in grater detail behind the scenes, and as a result the IERI sponsored a research program for the investigation by a team at Cornell University to be conducted in parallel with a similar study planned at the Building Research Station in England.

Background to the Study

The systematic study of discomfort effects from glare begins with the work of the research teams working in the United States in the 1920's. If earlier work was done, it has not found its way into the general literature of lighting research. Various "expert" opinions on the limits of comfortable brightness were made from time to time, but they do not seem to have been based on any solid background of research.

In the mid-1920's Holladay, in collaboration with Luckiesh, published the results of a comprehensive investigation which has served as a model for later work and which is still the basis of much current practice due to its adoption by Harrison and Meaker for their Glare Factor tables and the concept of the Visual Comfort Index.[2,3,4,5]

From time to time, however, there have been doubts expressed of the validity of the experimental technique employed by Luckiesh and Holladay, particularly in respect to the very large number of criteria of discomfort employed in making the judgments of glare, and to a lesser extent of the "flashing," or momentary exposure of the source. Many further studies have been made employing more widely accepted methods and making use of statistical analysis of variance, so that there is now a satisfactory amount of reliable data for the proper appraisal of the problem. The basic expression for the relation between the variables which govern glare remains the same as the one used by Luckiesh and Holladay, but the weight given to the various different factors is not the same.[6,7,8,9]

All these studies were limited by the design of the apparatus to a consideration of relatively small sources. Such studies covered most of the conditions normally encountered in practice in lighted streets or in the interiors of buildings, and the results agreed in the basic expression for the formulation of the relation between the physical variables which govern glare discomfort. This expression is:

AUTHORS: Building Research Station, Garston, Herts, England, and Cornell University, Ithaca, N. Y., respectively. This paper reports the progress on Research Project No. 59 of the Illuminating Engineering Research Institute.

$$\text{Glare constant } G = \frac{B_s^p W^q}{F^r} \qquad (1)$$

Where B_s is the luminance of the source
W is the apparent size of the source
F is the surround luminance.

It now seems likely that agreed values for the indices p, q, and r can be derived from more comprehensive recent researches. All these agreed on assigning values of p, q and r in the ratio of approximately 1.6:0.6:1.0.

In the Cornell 1956 paper it was shown that the classical glare formula could only be valid over that range of conditions where the adaptation level is governed primarily by the surround luminance F, and where it is virtually independent of the source luminance B_s. Such conditions only apply when the source is not very large and does not produce a very high illumination at the eye.

If the source is large, the adaptation level is influenced by the source and is determined only partly by the surround luminance. In such circumstances the formula is no longer valid in the form given. It has been possible to solve many practical problems, such as that of glare from large windows or luminous ceilings, by extrapolation of the existing experimental data. When the source of glare is very large, say of the order of 0.1 steradians or above, it has been found empirically that a rather better approximation to the degree of glare is sometimes obtained if the F term in the formula is taken as the average luminance of the whole field of view including the source, than if F is taken strictly as the surround luminance alone.

In view of the increasing tendency to the employment of large sources in lighting practice, it was felt to be open to objection that much lighting comfort calculation should be based on extrapolated data. A detailed study of the effect of very large sources on glare discomfort was considered necessary for progress.

Experimental Arrangement

The experimental arrangement at Cornell and at the Building Research Station is based on a very large source consisting of a bank of closely packed fluorescent lamps whose light is diffused by an opal plastic screen, so presenting a large surface of uniform brightness to the observer. A system of dimmers permits a smooth control, either by the subject himself or the experimenter, of the luminance of this source from about 1.0 to 4500 footlamberts (0.002 to 10 candelas per square inch). A series of masks placed over the large source, together with adjustment of the observer's distance from the source, gives a range of apparent source size from 10^{-3} steradians up to the full visual field, the latter being obtained in the British apparatus by a system of plane mirrors set around the observer when positioned close to the opal screen. (Fig. 1).

Figure 1. Large area glare source with mirror attachment for full field studies.

The surround luminance in the British apparatus is provided by other fluorescent lamps, also on dimmers, set in a system of screens, white towards the observer, black towards the source, so constructed that a substantially uniform surround

Figure 2. Light surround arrangement.

luminance is seen by the observer with as little mutual interference of the surround luminance and the source luminance as possible (Fig. 2).

For the dark surround condition, all surfaces were of black cloth.

Both source and surround luminance are monitored separately by photoelectric photometers suitably screened to limit their field of view.

The color of the lamps was chosen with some care to give an acceptable approximation to daylight and to the color of fluorescent lighting in common use at high levels of illumination.

The method of dimming control is different in the two cases. Thyratron control is employed in England, the lamps running on the 50-cycle supply. This method was chosen chiefly because there was experience with this method, and because a firm was willing to supply and maintain the control gear under the onerous conditions of the experiment. It was also thought possible, on theoretical grounds, that from the nature of thyratron control flicker might be independent of brightness. This arises from the fact that flicker becomes more noticeable at high luminances, and also more noticeable when the light-time ratio is less.[10] Since thyratron control operates by a chopping action on the waveform, and hence introduces a lesser light-time ratio at lower luminances, this effect would run counter to the reduction in flicker perception at lower luminances, the objective factor balancing out the subjective. Hence flicker might be substantially constant throughout the range of available luminance. In fact, instabilities in the control system resulted in flicker being arbitrarily noticeable or absent at different points on the luminance range. Single lamp ballasting on one phase was the only practicable method.

At Cornell adjustment of the source luminance is obtained by a variable inductance control. Each lamp has in series with it a small variable autotransformer across which is placed a specially wound 39 millihenry choke. This circuit is fed by a 440-volt 400-cps generator. The lamp cathode heaters are fed from filament transformers connected across a variable autotransformer and a 60-cps power supply. Positive coupling between the lamp autotransformers, the cathode heater autotransformers and a variable capacitor for the 400-cps generator power factor correction is provided by a rack and pinion gear system. The rack is operated by a forward and reverse control, such that the whole bank of lamps can be raised or lowered in light output smoothly over a large range of luminance by merely operating the push-button forward and reverse switch. This method of dimming has the advantages of smooth, stable lamp operation over a wide range with provision for balancing and trimming individual lamps, and at the same time with complete freedom from flicker.

Experimental Procedure

The experiments were conducted by means of the Multiple Criterion Method (Appendix I) with the observer in control of the source luminance.

The observer sat in the controlled environment which surrounded him completely. The experimenter sat apart in another room, communication between experimenter and observer being confined to brief signals when the various judgments were completed. The observer looked directly at the source, but was not asked to fixate, but rather to allow his gaze to be as free as in a room. In fact the phototropic effect of the source held the observer's attention for most of the time.

To begin, the source was off and the background set, and the observer sat for approximately 10 to 15 minutes to adapt to the conditions. It had previously been explained what was demanded of him, first, to raise the brightness of the source himself by means of the dimming control knob until the threshold of glare (Criterion D) was reached, and this he proceeded to do after the necessary period of adaptation had elapsed. The setting for Criterion D was signalled to the experimenter, who signalled his acceptance, and the observer then slowly raised the brightness of the source again, allowing pauses for adaptation, until the next degree, just acceptable glare (Criterion C) was reached. Great emphasis was laid on the need to adapt fully to the new conditions and a signal was not accepted until at least two minutes had elapsed since receiving the previous signal. Criterion B, just uncomfortable glare, came next, and finally Criterion A, just intolerable glare.

A further long period of re-adaptation with the source fully dimmed was now necessary to recover from the local retinal light adaptation caused by looking at the bright glaring source. This period was approximately ten minutes, which was rather more than twice the time necessary for the afterimage of the source to disappear. After the period of re-adaptation, a new series of judgments was made.

The variation of the size of the source as seen by the observer was obtained by a series of masks over the source, and also by moving the observer nearer or farther from the source. It has always been assumed that the governing factor in glare discomfort in the spatial sense is the apparent and not the real size of the source, *i.e.*, a large source seen from afar will give the same degree of glare as

a smaller source seen closer, if the solid angle subtended at the eye is the same. It was decided to check this point again (it had already been checked before)[11] by overlapping on the sizes of the masks and the viewing distances. The procedure was, therefore, to set the observer initially at the greatest distance (*c.* 15 feet) from the smallest mask, for the first set of glare judgments, and to set him successively nearer, in equal ratio steps of apparent source size, to the screen, then to change the mask to the next largest size, and to set the observer back to his original starting point, and so on. His final set of judgments was made with the source occupying his full field of vision.

At a later stage of the work, when it had been established that any size-constancy effect, if it existed, was of only secondary importance, the observation time was reduced by eliminating most of the overlap on source size and distance.

Selection of Observers

Ideally, all experiments destined to lead to general recommendations on lighting should be conducted with a sufficient number of observers to represent the whole population to whom the recommendations will apply. Consequently, while the standards of lighting provided in a private office can very well be set by the occupant himself, to be applicable to all office standards should be based on the judgments of a representative group of office workers.

Unfortunately studies of visual comfort are laborious and take a long time because continual repetition of a judgment by the same observer and under the same conditions is necessary in order to assess the average judgment with sufficient precision. Unless, therefore, the experiment can be so designed that many observers can make judgments simultaneously (and this is rarely possible in an experiment) it becomes necessary for the experimenter to rely on the judgment of fewer observers than are ideally required.

Experience over many years has shown that it is then much better if observers are carefully selected, not necessarily for the numerical precision of the results they give, but for their general cooperation. This characteristic can be summed up by saying that they should be good human meters. They should be co-operative, intelligent, quick and keen to appreciate the points of technique of the experiment. They should give of their best, without in any way needing to have any knowledge of the trend of their results as a reward. They should have no preconceived theories about the experiment on which they are engaged; they should be indifferent about the *result* of the experiment, but conscientious for the *success* of the experiment.

Selection is made as the result of a pilot experiment during which repeated observations under controlled conditions are made by each observer. The selected observers will have achieved a sufficient familiarity with the technique of subjective judgment by the end of this pilot experiment. As "human meters" they will be calibrated. They are not *trained*, for they have formed their *own* assessment of the criteria without constraint, but they *are experienced*.

At Cornell the observers fall within a limited age group (18-25), are all male engineering students, and so do not come from a fully representative section of the population. This choice was deliberate, however, because experience has shown that technically trained people are more cooperative in these somewhat onerous subjective studies, and more likely to meet the requirements for good human meters.

Results

When the work at Cornell is complete, about 10,000 observations will have been collected from a total of 20 observers. At the time of writing the study has some way to go, and so no conclusions can be drawn with certainty. The British end of the study was planned deliberately to act as the spearhead of the investigation, because a small panel of skilled observers was available, and so the full-scale study was pushed ahead without any pilot study. At Cornell, on the other hand, effort had to be put into recruiting a group of young engineering students and giving them experience in making judgments of glare under a limited range of conditions before they got busy on the full scale experiment. The Cornell data are therefore at the moment confined to observations from ten observers on one source of 0.1 steradians with three levels of surround luminance.

Complete sets of observations were made at the Building Research Station, first in the dark surround, next in a light surround of 50 footlamberts luminance, and finally in a light surround of 10 footlamberts luminance with a full range of source size. At the time of the preparation of this paper four observers had made complete sets of observations under all conditions. The data from so few observers cannot of course have any practical value other than to illustrate the nature of the problem being studied. The extensive data which should emerge from the full Cornell and British studies must be awaited for any definite statement.

However, the data of these few observers make rather an interesting story, and they may be useful to record a few results.

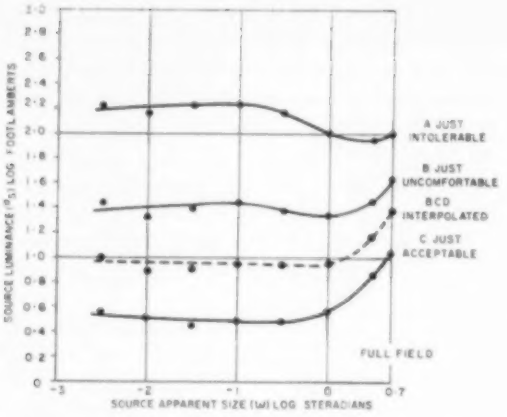

Figure 3. Equal glare curves relating source size and luminance; four observers, dark surround.

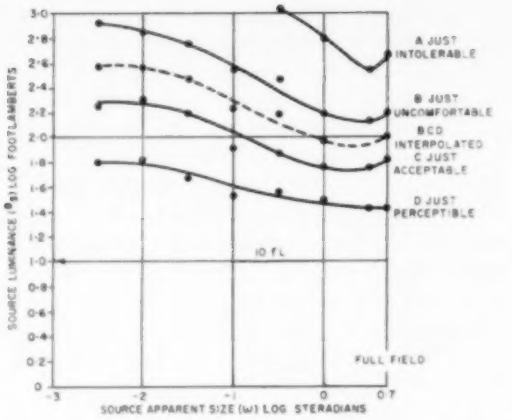

Figure 4. Equal glare curves relating source size and luminance; four observers, surround ten footlamberts.

Summary of Results

Dark Surround—Each of four observers made four complete sets of judgments with the dark surround, amounting to 272 judgments in all per observer. The observations were made in groups of 16, that is, four judgments (Criteria D, C, B, A) at four distances from one given size of mask over the source. Each group of 16 judgments, with adaptation time, took about one hour, which was as long as an observer could be expected to function with significant fatigue. Some time, hours or days elapsed between each group of judgments. In spite of this, agreement between any one observer's settings on different occasions for the same conditions was good.

On the other hand, the four observers differed widely in their mean settings. This may have been due to different degrees of sensitivity to glare, undoubtedly exaggerated by the unnatural condition of a bright source seen in a dark ground. The possibility of inadequate adaptation also cannot be ruled out, although every effort was made to avoid this.

The chief features of the results (see Figs. 3 and 7) were:

(1) With a dark surround almost the same degree of glare discomfort arises no matter what the size of the source, up to a source size of about ⅓ to 1 steradian. (A window or luminous ceiling of 200 square feet in area seen 15 feet away subtends about 1 steradian at the eye.)

(2) As the source is increased in size to full field, the degree of glare gets less, after full adaptation has taken place.

(3) When the source is very large, glare is very sensitive to changes of brightness.

(4) The level of source brightness which causes "intolerable" glare is practically independent of source size up to full field—on the other hand the brightness which causes threshold glare in a dark surround is low with small sources but is higher with the full field.

Light Surrounds (10 and 50 footlamberts)—The main conclusion (see Figs. 4, 5, 6 and 7 from the light surround studies) are as follows:

(1) Whereas with the dark surround the size of the source had only a small influence on the degree of glare, with a light surround the size of the source has a more marked effect.

(2) The slope of the equal-glare *Bs/W* curves is

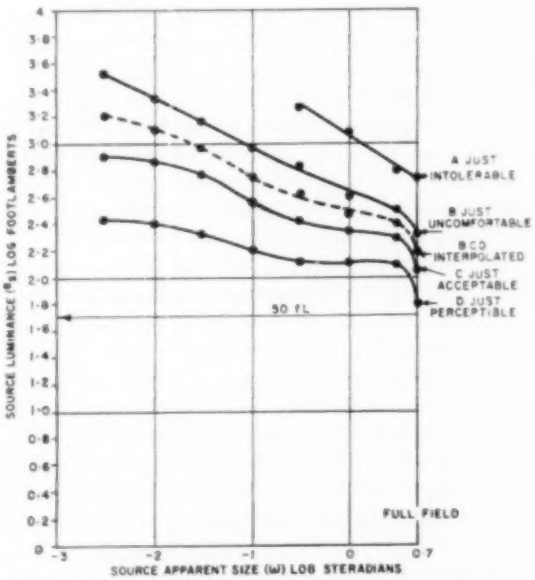

Figure 5. Equal glare curves relating source size and luminance; four observers, 50 footlamberts.

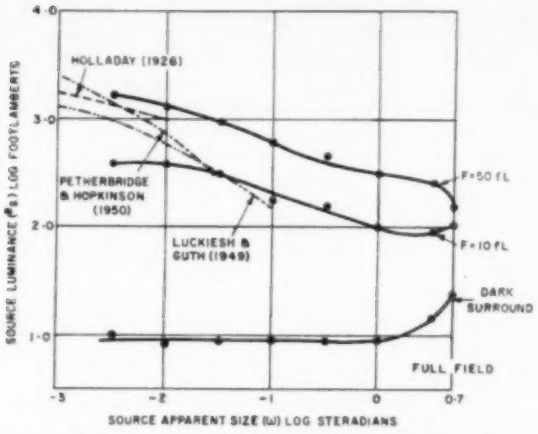

Figure 6. Comparison of interpolated BCD values from present study with values from other studies for 10-footlambert surround.

greater the higher the degree of glare. In other words, the size of the source has a greater effect on severe glare than on mild glare.

No useful purpose could be served by closer analysis of the scanty data. A full survey must await the completion of the Cornell studies.

It is, however, not possible to resist the temptation at this early stage to make a comparison with results of the earlier investigations. Fig. 6 shows the slopes of the earlier Bs/W equal-glare curve for a background of 10 footlamberts compared with the present data. The increase in slope reported by Luckiesh and Guth at about 10^{-1} steradians is not fully in evidence, and although some

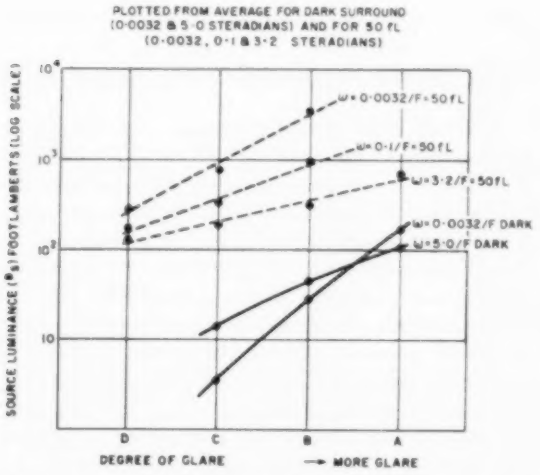

Figure 7. Diagrammatic relations between source luminance and degree of glare. Mean data from four observers.

discontinuity in the data does appear at this point, it was felt unwise on the basis of so little information to come to any conclusions in this matter.

It is equally not possible yet to indicate how the glare formula must be modified to account fully for the large source data. The simple power law expression is clearly not valid, since the equal glare curves on the log Bs/log W scale are no longer straight lines. Some calculations have been made to compare the results obtained experimentally with those that would have been arrived at by interpolation in the existing formula if the practice, referred to above, had been allowed of equating the F term, not to the actual value of the surround luminance, but to the average luminance of the whole field including the source itself. It is of interest to record that some degree of agreement was obtained, especially for the higher degrees of glare, and more especially if the F term expressed in footlamberts is equated to the illumination in footcandles received at the eye from the whole field, both source and surround. The weight given in the averaging of field luminance is thus made successively less towards the periphery of the field, so that the effect in the present case is to weight the central source more heavily than the peripheral surround.

We find that if the F term is determined in this manner, and substituted in the formula in the usual way, the values of the glare constant G so obtained are substantially constant for the Criterion A degree of glare, indicating that for this degree of glare the formula used in this way fits the data actually up to the full field. This, however, does not happen with the other degrees of glare to the same extent. It would therefore seem wise to defer further speculation about the eventual formulation of the final data until a clearer picture emerges from the Cornell studies.

Conclusion

As a report of work done, this paper is naturally premature, but some useful purpose may be served by the submission of the description of the experimental procedure and of the first results for discussion. The value of these first results cannot yet be assessed. Perhaps the most interesting indication so far obtained is the fact that, with large sources, a much smaller change in luminance is needed to produce a given change in degree of glare discomfort. If this finding is confirmed by a full Cornell study, it will mean that very much greater care in setting the brightness, of say, a luminous ceiling, is necessary than in the case of conventional luminaires. The form of the data would suggest that recommendations may possibly be expressed most usefully and most simply in the form of a

limiting ratio of the source brightness to the general surround brightness.

The experimental data from these investigations is likely to be of assistance in the study of the additive effects of glare. So far no attempt has been made to apply the available data to this purpose, but the failure of the simple concept of additivity forecast in the Cornell 1956 paper is borne out by the present data. As an auxiliary to the main study, an attempt was made with some success, to obtain numerical estimates of glare sensation magnitude.[12,13,14] If a sensation magnitude scale for glare discomfort can be established and used, the problem of the additive effects of glare should prove more tractable.

Acknowledgments

The authors wish to thank the Illuminating Engineering Research Institute for its help and financial assistance to the Cornell study. The British work is part of the program of the Building Research Board of the Department of Scientific and Industrial Research of Great Britain, and acknowledgments are made to the Director of Building Research for permission to publish this paper. The authors express their gratitude to their colleagues in England and the U. S. for their assistance.

Appendix I—Multiple-Criterion Technique of Subjective Appraisal

The Multiple-Criterion Technique was developed by one of us (R.G.H.) for the study of glare in lighted streets. It comes under the heading of what Guilford (Psychometric Methods, McGraw-Hill, 1954) calls "Methods of Successive Categories" but the essential feature, not mentioned by Guilford in any of his variants, is the control by the observer of the variable of the environment resulting in a feedback of information from the environment to the observer. In the study of glare, the observer can, by means of the control at his disposal, change the degree of glare from imperceptible to intolerable, with complete freedom.

When the observer has become thoroughly familiar with the situation, he is asked to set the controls to give the first criterion of glare. In the present experiments this was the criterion "just perceptible glare" (Criterion D). The next setting was described as "just acceptable glare" (Criterion C). This was a degree of glare one distinct step worse than "just perceptible glare" but still just not unacceptable. The third criterion was "just uncomfortable glare" (Criterion B), the point at which the glare, no longer acceptable, just began to cause a sensation of real discomfort. The fourth and final criterion was "just intolerable glare" (Criterion A), the point at which glare became just too uncomfortable to be tolerated for long.

During the course of the experiment proper, the observer would merely signal to the experimenter, in the recording room apart, the letters D, C, B, A, in succession. No worded description was therefore necessary.

Initially, however, a long period of training and experience in the use of the technique preceded the experiments proper, and observers did not partake in the experimental program until they were familiar with and confident in the use of the method.

(The effect of experience and training on the sensitivity to discomfort is known and has been expressed in the form of a probability relation between the sensitivities of trained observers and of the general population.[1,14,15])

The essential features of the method are:

(a) the control of the variables by the observer himself, producing a voluntary feed-back from stimulus to sensation, resulting in a refinement of judgement;

(b) the use of a succession of only four borderline criteria of glare sensation, each a readily recognizable threshold, and each so chosen that a big enough step in sensation separates the one from the next criterion, so that they will not be confused.

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June IE Features Office Lighting

IES Recommended Practice for Office Lighting is the first revised recommended practice to be issued since new footcandle levels were established in 1958. Watch for this important report in the June issue of IE. It should be a valuable tool for lighting men in selling and designing office installations. So should other editorial material planned for the issue—"Heating with Light," "Light and Air Conditioning," a special explanation of the "seissors" curve and graphic demonstrations of office tasks showing why they need the footcandle levels recommended.

Tensile and Thermal Stresses in the Envelope of High Brightness High Pressure Discharge Lamps

By WOLFGANG E. THOURET

High pressure xenon or mercury discharge lamps combine the high brightness of carbon arcs with the maintenance-free and clean operation of regular discharge or incandescent lamps. Their use in searchlights, movie projectors and for other special purposes is increasing steadily in this country and in Europe. The quartz envelopes of these lamps have to withstand considerable tensile and thermal stresses resulting from the high internal pressure and from temperature differences within the wall. This paper shows how the different stress components and their distributions can be calculated. Discussion of how approximate knowledge of the stress distribution can be utilized for obtaining optimum lamp designs and for estimating the feasibility of new lamp types is illustrated with practical examples.

HIGH brightness mercury or xenon discharge lamps with extremely high operating pressure have been developed since 1935 in Europe[1-17] and in this country.[18-27] Their main advantage is that they combine the high brightness of carbon arcs with the maintenance-free and clean operation of regular discharge or incandescent lamps. Xenon high pressure lamps, in addition to their high brightness, have the unique characteristic of a spectral energy distribution similar to that of natural daylight. This makes them desirable light sources for color matching and other applications that require accurate duplication of daylight.

The use of high brightness high pressure lamps is increasing steadily as more new types of optical equipment, based on the lamps' favorable properties, are designed and manufactured. Beggs[26] has given a detailed description of the many actual and potential applications for mercury and mercury-xenon short arc lamps in searchlights, beacons, and special optical devices. Ulffers[30] describes a movie projector with a 1000- or 2000-watt xenon short arc lamp that is successfully used in medium sized European theatres. Cowett[31] and D'Arcy and Seda[32] have reported on the design of a 16 mm movie projector with a 900-watt xenon high pressure short arc lamp. Stabe[28] has developed a novel type of multiple direct recording oscillograph based on a 100-watt mercury high pressure short arc lamp with very high brightness and extremely small source size. This instrument[33] is in widespread use in European countries and a similar design has been introduced in this country.[34] According to Hoffmann,[29] a color matching unit with a 160-watt xenon high pressure short arc lamp has been made available for the textile, paper, and related industries. These are some typical examples from the diversified field of application for high pressure high brightness discharge lamps.

Lamps of this category are available in a wide range of wattages between 75 watts and several kilowatts. They have been developed in two basically different forms:

(1) The short arc or compact source type, which is characterized by a small electrode spacing of less than one millimeter to approximately 10 mm and by a spherical or ellipsoid bulb of relatively large diameter, when compared to the electrode spacing. This type is also characterized by the so-called electrode-stabilized form of its arc discharge.[35]

(2) The long arc or capillary type with wall-stabilized arc discharge burning in a narrow tubular envelope with relatively wide electrode spacing. This form of high brightness high pressure lamp usually requires high specific bulb loading and, therefore, is operated in many cases with forced cooling by water or compressed air.

The internal operating pressure of these lamps amounts at least to several times atmospheric pressure and may reach 75 atmospheres (1100 pounds per square inch). Therefore, their bulbs, which

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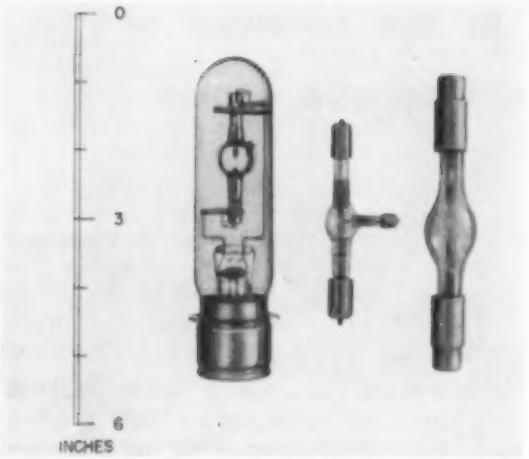

Figure 1. Typical small wattage short arc high pressure lamps. From left to right: 75-watt mercury lamp in outer bulb with pre-focus base (See Table I, No. 1); 100-watt mercury lamp with extremely short arc and very high brightness (Table I, No. 3); 150-watt xenon lamp (Table I, No. 5).

usually consist of pure fused quartz, have to withstand considerable tensile stresses. In addition, during lamp operation the bulb wall is subjected to substantial thermal stresses resulting from temperature differences, especially in lamps with high specific bulb loading or with forced cooling.

These tensile and thermal stresses in the bulbs of high brightness high pressure lamps present relatively new and unfamiliar problems to the design and production engineer. It is the purpose of this paper to show how the different stress components and their distribution within the bulb wall can be calculated. Further discussion shows how approximate quantitative knowledge of the stress distribution can be utilized for obtaining optimum lamp designs and for estimating the practical feasibility of new lamp types with certain desired properties.

Design Data of Practical Lamp Types

The computation of tensile and thermal stresses in the lamp envelope and the application of the results to lamp design can be explained best on the basis of practical lamp data. For this purpose Table I reviews the main dimensions and characteristics of a number of high brightness lamps that have been developed and are made available by several manufacturers. Figs. 1 to 3 give the outward appearance and relative size of some typical examples selected from these lamps. Fig. 1 presents three small wattage short arc types with spherical or ellipsoid-shaped bulbs in the 75- to 150-watt range; Fig. 2 two relatively large short arc lamps of 1800 and 2500 watts; and Fig. 3 two water-cooled long-arc lamps with cylindrical arc tubes of 1000 and 6000 watts.

The lamp pictures and the data given in Table I show that the envelopes of high brightness lamps are either cylindrical, spherical or ellipsoid-shaped vessels with diameters ranging from a few millime-

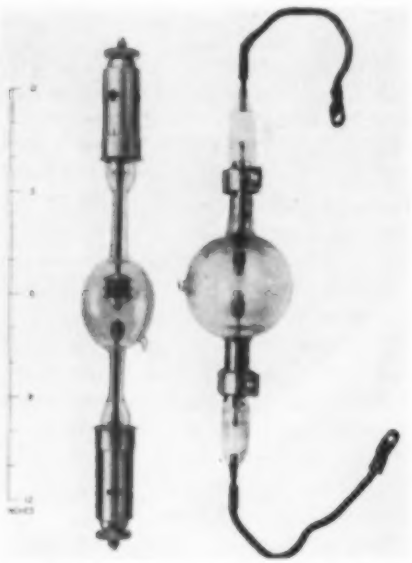

Figure 2. Typical large wattage short arc high pressure lamps. Left: 1800-watt xenon lamp (No. 16); right: 2500-watt mercury or mercury-xenon lamp (No. 17).

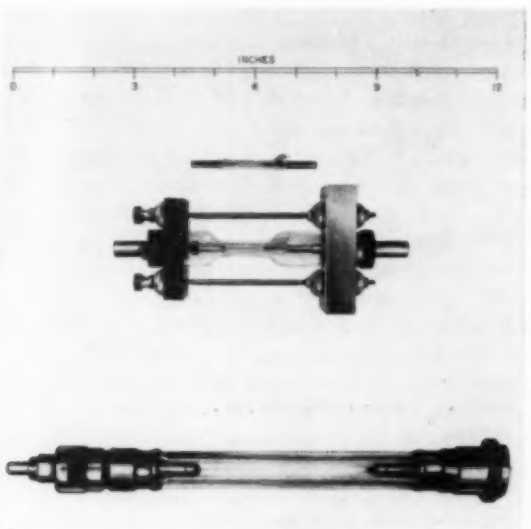

Figure 3. Typical long arc high brightness lamps with water cooling. Above: 1000-watt mercury lamp without and within water cooling jacket (No. 19); below: 6000-watt xenon lamp within water cooling jacket (No. 21).

TABLE I—Main Data of Some Available Types of High Brightness High Pressure Discharge Lamps.

No.	Lamp Watts	Type Designation	Gas Filling	Internal Operating Pressure Approx. atm.	Arc Tube Maximum Outer Diameter mm	Arc Tube Wall Thickness Approx. mm	Arc Length mm	Average Brightness Candles/mm²	Initial Lumens	Rated Life Hours
				Short Arc Lamps						
1	75 a-c	HBO 74[d]	Hg-Ar	60	14	1.8	3	44	2500	400
2	100 d-c	548A-1[b]	Hg-Ar	40	12.7	1.8	0.4	1000	1000	100
3	100 d-c	HBO 107/1[d]	Hg-Ar	60	12	1.8	0.3	1000	1050	100
4	125 a-c	ME/D 125[e]	Hg-Ar	25-30	30	2-3	1	500	4500	100
5	150 a-c	510 C-1[b]	Xenon	20	20	2-2.5	3.85	75	3000	300
6	200 a-c/d-c	HBO 200[d]	Hg-Ar	50	18	2.4	2.5	350	9500	200
7	250 a-c	SAH-250A[c]	Hg-Ar	30	16	2-3	2.5	175	10000	100
8	250 a-c	ME/D 250[e]	Hg-Ar	25-30	30	2-3	3.75	200	10500	500
9	375 a-c	XC 375[c]	Xenon	6-8	40	2-3	6	50	8500	500
10	500 a-c/d-c	HBO 500[d]	Hg-Ar	35	32	3-3.5	4.5	200	21500	200
11	800 a-c	SAH-800C[c]	Hg-Ar	10	44	3-3.5	8.5	125	40000	300
12	900 d-c	538 C[b]	Xenon	35	40	3-4	6.5	180	29000	300
13	1000 a-c	SAH-1000A[c]	Hg-Ar	25	54	3-4	6.5	250	52000	300
14	1000 a-c	517 A[b]	Hg-Ar		40	3-4	6.5	240	52000	300
15	1000 d-c	XBO 1001[d]	Xenon	25	40	3-3.5	3.4	400	32000	1200
16	1800 d-c	XBO 2001[d]	Xenon	25	52	3-3.5	4.2	500	65000	1000
17	2500 a-c	SAH 2500A[c]	Hg-Ar	15	73	3.5-4	10	225	125000	200
18	2500 a-c	553 B[b]	Hg-Xe	20	55	3.5-4	9	220	125000	100
				Long Arc Lamps (Water-Cooled)						
19	1000 a-c	AH-6[e]	Hg-Ar	75	6	2	25	250	65000	100
20	5000 a-c	XA/U[c]	Xenon	15-18	20	1.2-1.5	65	14-18	140000	100
21	6000 a-c/d-c	XBF-6000[d]	Xenon	25	11	1.5	110	30	215000	1000

NOTES: The table is far from complete, especially concerning the lamp types available in other countries. For a complete list of the short arc lamps available in this country see *IES Lighting Handbook*, Third Edition, 1959, Section 8, Fig. 8-94, page 8-115. The lamps listed under Nos. 13, 14, and 17, are also available with Mercury-Xenon filling (total operating pressure 5 atm. greater).
[c]General Electric, USA
[b]Hanovia, USA
[c]Westinghouse, USA
[d]Osram, West Germany
[e]Siemens-Ediswan, Great Britain

ters to several inches and with wall thicknesses between one and four millimeters. During lamp operation they have to withstand internal pressures from 10 to 75 atmospheres of xenon gas, of mercury vapor, or of a combination of both in mercury-xenon lamps. The maximum argon pressure in lamps with mercury-argon filling amounts only to a small fraction of one atmosphere. In these lamps the mercury vapor pressure contributes predominantly to the tensile stresses within the bulb wall.

Only a certain part of the total wattage W_L consumed in a lamp is converted into radiation that passes through the bulb wall without absorption loss. Other parts of W_L are absorbed as radiation by the envelope or heat it to the relatively high operating temperature of 600-900C by means of heat conduction, convection, and diffusion of electrons and ions from the arc and the electrodes to the bulb wall. These amounts of energy pass through the wall by heat conduction, thus creating a temperature gradient dT/dr which causes the thermal stress condition. dT/dr depends upon the total thermal energy W_Q that is conducted through the bulb wall per surface unit, as follows:

$$W_Q = \gamma \frac{W_L}{s} = \gamma \cdot W_s = -\lambda \frac{dT}{dr} \qquad (1)$$

(s: total inner bulb surface; W_s: average bulb surface loading, λ: thermal conductivity of bulb material, T: temperature within wall, r: bulb radius) $\gamma = W_Q/W_L$ is the relation between the wattage conducted through the bulb wall as heat and the total lamp wattage. It varies somewhat with different gas fillings and other arc discharge parameters. However, for the purpose of calculating thermal stresses in this paper the constant value $\gamma = 0.3$ is used (see Elenbaas[36]). Consideration of the variations of γ would make the computation of thermal stresses considerably more complicated. Besides this, there is only little quantitative information available on these variations.

Calculation of Tensile and Thermal Stress Components

The theories of elasticity and strength of materials supply basic equations for determining the distribution of tensile and thermal stresses within the wall of vessels under internal pressure at elevated temperatures.[37-43] These equations have been developed for computing the dimensions of steam boilers or diesel engine cylinders and the solution of similar problems of mechanical engineering. They were adapted to the conditions and parameters of the quartz envelopes of high pressure lamps and are given here for cylindrical and spherical bulb shape.

The following designations and numerical values

for material constants are used. They all refer to clear fused quartz because this is virtually the only bulb material in use for high pressure lamps.

Coefficient of linear thermal expansion	$\alpha = 5.9\ 10^{-7}$
Heat conductivity (average between 0 and 600C)	$\lambda = 0.017$ watts/degree · cm
Modulus of Elasticity	$E = 7 \times 10^5\ kg/cm^2 = 10 \times 10^6$ psi
Poisson's ratio	$\mu = 0.16$
Ultimate tensile strength at 800C (at 20C: approx. 11000 psi[44])	$\sigma_U = 14 \times 10^3$ psi
Internal Lamp operating pressure	P
Inner bulb radius	r_i
Outer bulb radius	r_o

The tensile stress condition within the bulb wall, which is caused by the internal pressure, can be described in cylindrical bulbs by three stress components (radial component σ_{Pr}, tangential component $\sigma_{P\vartheta}$, and axial component σ_{PZ}):

$$\left.\begin{aligned} \sigma_{Pr} &= P \cdot \frac{r_i^2}{r_o^2 - r_i^2}\left(1 - \frac{r_o^2}{r^2}\right) \\ \sigma_{P\vartheta} &= P \cdot \frac{r_i^2}{r_o^2 - r_i^2}\left(1 + \frac{r_o^2}{r^2}\right) \\ \sigma_{PZ} &= P\ \frac{r_i^2}{r_o^2 - r_i^2} \end{aligned}\right\} \qquad (2)$$

σ_{Pr} and $\sigma_{P\vartheta}$ are functions of the bulb radius r within the wall. σ_{PZ} is constant, as the tensile force producing longitudinal extension of the cylindrical bulb is distributed evenly over the cross-sectional area of the wall.

In spherical bulbs there are two equal tangential components in addition to the radial component:

$$\left.\begin{aligned} \sigma_{P\vartheta} &= P \frac{r_i^3}{2(r_o^3 - r_i^3)}\left(2 + \frac{r_o^3}{r^3}\right) \\ \sigma_{Pr} &= P \frac{r_i^3}{r_o^3 - r_i^3}\left(1 - \frac{r_o^3}{r^3}\right) \end{aligned}\right\} \qquad (3)$$

The tensile stresses thus are directly proportional to the internal pressure and otherwise depend only upon the bulb dimensions. They are independent of the bulb material properties. For bulbs with small wall thickness t in comparison to their radius, it can be assumed that $r_i \approx r_o \approx r$ and the equations (2) and (3) are simplified to

$$\left.\begin{aligned} \sigma_{P\vartheta} &= P \cdot \frac{r}{t} \\ \sigma_{PZ} &= P \cdot \frac{r}{2t} \end{aligned}\right\} \qquad (4)$$

for cylindrical, and

$$\sigma_{P\vartheta} = P \cdot \frac{r}{2t} \qquad (5)$$

for spherical envelopes. σ_{Pr} becomes meaningless in both cases. Equations (4) and (5) show that, in theory, a spherical bulb can withstand approximately twice the internal pressure that can be held by a cylindrical bulb of the same diameter and wall thickness under the same thermal stress condition.

The thermal stress components as a function of the bulb radius within the wall are for cylindrical envelopes:

$$\left.\begin{aligned} \sigma_{Tr} &= W_Q \cdot \frac{C}{2}\left[r_i \cdot \log_e \frac{r}{r_i} + \frac{r_o^3 r_i}{r_o^2 - r_i^2}\left(\frac{r_i^2}{r^2} - 1\right) \log_e \frac{r_o}{r_i} \right] \\ \sigma_{T\vartheta} &= W_Q \cdot \frac{C}{2}\left[r_i + r_i \log_e \frac{r}{r_i} - \frac{r_o^2 r_i}{r_o^2 - r_i^2}\left(\frac{r_i^2}{r^2} + 1\right) \log_e \frac{r_o}{r_i} \right] \\ \sigma_{TZ} &= W_Q \cdot C \cdot \mu\left[\frac{r_i}{2} + \frac{r_i}{\mu} \log_e \frac{r}{r_i} - \frac{r_o^2 r_i}{r_o^2 - r_i^2} \log_e \frac{r_o}{r_i} \right] \end{aligned}\right\} \qquad (6)$$

and for spherical bulbs:

$$\left.\begin{aligned} \sigma_{T\vartheta} &= W_Q \cdot C\left[r_i - \frac{r_i^2}{2r} - \frac{(r_o - r_i)\, r_i^4 r_o^2}{r_o^3 - r_i^3}\left(\frac{1}{2r^3} + \frac{1}{r_i^3}\right) \right] \\ \sigma_{Tr} &= W_Q \cdot C\left[r_i - \frac{r_i^2}{r} + \frac{(r_o - r_i)\, r_i^4 r_o^2}{r_o^3 - r_i^3}\left(\frac{1}{r^3} - \frac{1}{r_i^3}\right) \right] \end{aligned}\right\} \qquad (7)$$

with

$$C = \frac{\alpha \cdot E}{\lambda(1 - \mu)}. \qquad (8)$$

The equations show that the thermal stresses are directly proportional to W_Q, the amount of heat conducted through the bulb wall. Thus, the bulb surface loading has the same linear influence on the thermal stresses as the internal pressure has on the tensile stresses. The thermal stresses further depend linearly upon the factor C which, according to equation (8) is determined by material constants. The term in brackets in equations (6) and (7) represents bulb dimensions only, with one exception at σ_{TZ}, where Poisson's ratio μ appears within the bracket. However, this figure is assumed to have the same value for quartz, all types of glass, and all similar brittle materials that could come under consideration for high pressure lamps.[39] Therefore, it is constant for all cases discussed here. μ stands for the ratio between axial elongation and lateral contraction in a given material under tensile stress.

Equation (8) shows that the thermal stresses depend linearly upon the thermal expansion coefficient and the heat conductivity of the bulb material. For the numerical computations average values of these constants are used. Their variations with temperature are not considered more accurately because this would introduce complications and would not substantially improve the results due to the lack of reliable information. Equation (8) in addition demonstrates the fact that fused quartz is particularly suitable as bulb material for high brightness lamps not only because it can stand high temperatures but also on the basis of its low thermal expansion and its relatively high heat conductivity.

Practical Examples of Stress Distribution In Bulb Walls of Manufactured Lamp Types

The actual amount and distribution of stresses in existing lamp types shall be demonstrated now by practical examples. Fig. 4 shows all stress components as determined by means of equations (3) and (7) within the wall of a spherical 75-watt short arc lamp with an operating pressure $P = 60$ atm. and a bulb surface loading $W_s = 25$ watt/cm.^{2} The other data and dimensions of this lamp are listed in Table I under No. 1. The tangential component of the tensile stress is the largest and amounts to nearly 1400 psi at the inner wall. It decreases across the wall to about 900 psi at the outer radius. The tangential component of the thermal stress $\sigma_{T\theta}$ shows a different pattern. At the inner wall it is negative indicating compressive stress. It passes through a neutral zone ($\sigma_{T\theta} = 0$) at approximately the center of the wall and turns into a tensile stress of 170 psi at the outer radius. $\sigma_{P\theta} + \sigma_{T\theta}$ together result in a tensile stress which is approximately constant across the wall, amounting to about 1100

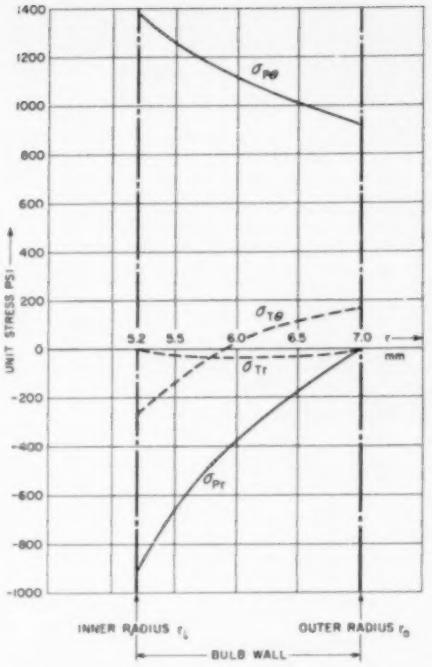

Figure 4. Tensile and thermal stress distribution within the bulb wall of small spherical short arc lamp. Inner radius $r_i = 5.2$ mm; outer radius $r_o = 7$ mm. Lamp wattage $W_L = 75$ watts; operating pressure $P = 60$ atm $= 880$ psi; bulb surface loading $W_s = 25$ watt/cm^2 $= 160$ watt/sq. in. (Table I, No. 1).

psi. Such uniform stress distribution is most desirable from the point of view of material utilization. Therefore, in this lamp type an optimum balance between internal pressure, bulb surface loading and bulb dimensions seems to be achieved. The radial components σ_{Pr} and σ_{Tr} are compressive stresses of negligible amounts which dissappear both at the outer wall.

Fig. 5 presents the stress components in the bulb of a relatively large spherical short arc lamp ($r_o = 25$mm, $W_L = 1800$ watts, other data similar to the lamp listed under No. 16, Table I). The stress distributions are similar to those of the small lamp discussed above. Characteristic quantitative differences are the following: The tensile stress $\sigma_{P\theta}$ is nearly constant across the wall because the wall is thinner in comparison to the bulb radius. The thermal stresses are greater due to higher bulb surface loading, greater wall thickness and greater bulb radius (see Figs. 7 to 11). $\sigma_{P\theta}$ and $\sigma_{T\theta}$ together result in a tensile stress that increases toward the outer wall to a maximum value of approximately 1550 psi.

Fig. 6 gives the stress components as determined by equations (2) and (6) within the wall of a cylindrical water-cooled long arc lamp. For data

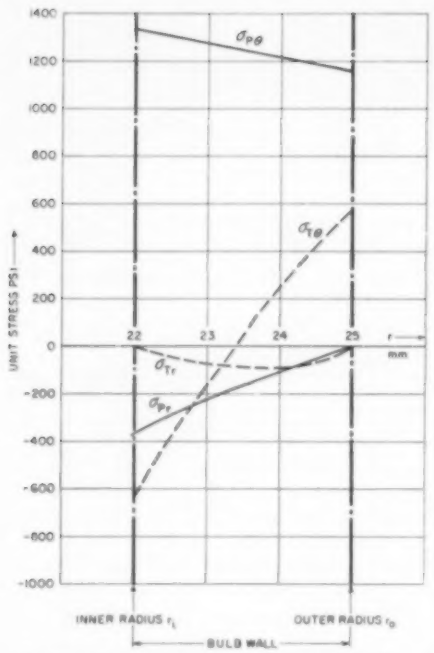

Figure 5. Tensile and thermal stress distribution within the bulb wall of a large spherical short arc lamp. r_i = 22 mm; r_o = 25 mm; W_L = 1800 watts; W_s = 32 watt/cm² = 200 W/sq. in. P = 25 atm = 370 psi (similar to No. 16, Table I).

and dimensions of this lamp type see No. 21, Table I. Because of the extremely high bulb surface loading ($W_s = 220$ watt/cm²) in this lamp the thermal stress components $\sigma_{T\theta}$ and σ_{TZ} are greater than the tensile components $\sigma_{P\theta}$ and σ_{PZ}. The axial component σ_{TZ} contributes by far the greatest stress at the outer wall with 3300 psi. The tensile stresses are of lesser importance. At the inner wall, they are compensated entirely by the compressive thermal stresses. The radial components again are negligible.

The total stresses in the lamp envelopes described by Figs. 5 and 6 are not uniform across the bulb wall. The sum of tensile and thermal stresses increases considerably from the inner towards the outer bulb surface. In the water-cooled lamp there is even a change from compressive stress at the inner wall to a high tensile stress at the outer wall. This means that the lamp designs utilize only partly the inherent strength of the bulb material. In theory, the desirable uniform stress distribution (as it seems to exist in the lamp described by Fig. 4) can be achieved best when tensile and thermal stress components contribute approximately equal amounts to the total stress.[42] However, in most practical cases it is impossible to meet this condition because the necessary values of pressure, bulb surface loading, and wall thickness are not compatible with other lamp design requirements.

Determination of Theoretical Strength Of Lamp Envelopes

The theoretical strength of a lamp envelope can be characterized by a "safety factor" n. Following the usual practice in mechanical engineering this factor is defined as:

$$n = \frac{\sigma_U}{\sigma_W} \qquad (9)$$

σ_U is the "Ultimate Strength" of the material, *i.e.*, the tensile stress at which fracture occurs. σ_W is the "working stress" or the maximum stress that can be considered "safe" for reliable operation of the particular lamp during its rated life. In order to judge the theoretical strength of a given lamp, it is necessary to compute the maximum stress that should actually occur in the envelope according to the above equations and to determine the safety factor n. The resulting value of n is to be compared with the safety factor of other existing lamp types that are known to be reliable in operation.

The theoretical maximum stress in a given lamp envelope can be found as follows: The practical examples discussed above show that the tangential and axial components are the main stresses. The thermal components are proportional to the bulb surface loading W_s and the tensile components grow linearly with increasing internal pressure P. Therefore, in a lamp with high pressure and small surface loading, it is possible that $\sigma_{P\theta}$ at the inner wall ($\sigma_{P\theta_i}$) supplies the maximum stress. As a rule, however, $\sigma_{P\theta_i}$ will be compensated, at least partially, by $\sigma_{T\theta_i}$, which is always a compressive stress. Thus,

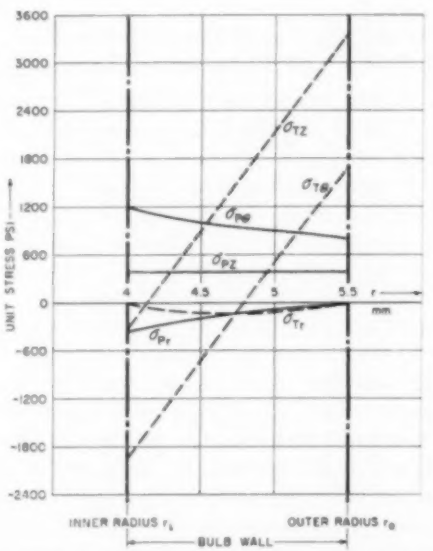

Figure 6. Tensile and thermal stress distribution within the bulb wall of a water-cooled long arc lamp. r_i = 4 mm; r_o = 5.5 mm; P = 25 atm = 370 psi; W_s = 220 watt/cm² = 1420 watt/sq. in. (Table I, No. 21).

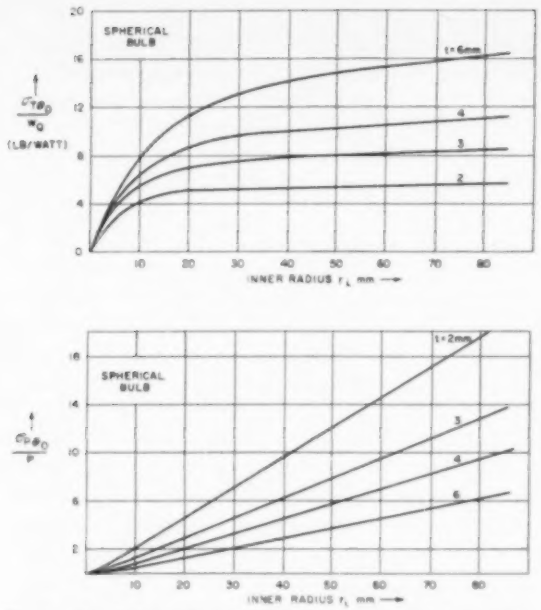

Figure 7. Spherical quartz bulbs: Tangential components of tensile and thermal stress at the outer bulb wall as a function of inner bulb radius and wall thickness.

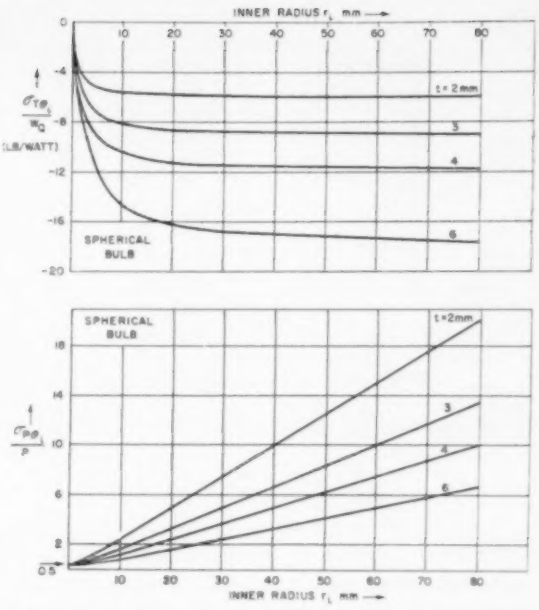

Figure 8. Spherical quartz bulbs: Tangential components of tensile and thermal stress at inner bulb wall as a function of inner bulb radius and wall thickness.

in most cases, the maximum stress will be found at the outer wall, where both the thermal stress $\sigma_{T\vartheta_0}$ and the tensile stress $\sigma_{p\vartheta_0}$ are positive. In cylindrical lamps, the sum of the axial components $\sigma_{pz} + \sigma_{Tz_0}$ has to be computed in addition to $\sigma_{p\vartheta_0} + \sigma_{T\vartheta_0}$ in order to determine which of these represents the maximum stress. Besides this, it is recommended to compute the total stress at the inner wall, because, as explained above, in certain cases this may be larger than the total stress at the outer wall.

The numerical amounts of the main stress components at the outer and at the inner wall, which are necessary for these computations, can be read from the curves of Figs. 7 to 11. Figs. 7 to 10 give the tangential components of both the thermal and the tensile stresses at the outer and inner bulb wall for cylindrical and spherical envelopes as a function of the inner radius r_i and the wall thickness t. Fig. 11 shows for cylindrical bulbs the axial component of the thermal stress at the outer wall (σ_{Tz_0}) and the axial component of the tensile stress which is constant across the bulb wall. These curves have been computed by equations (2), (3) and (6), (7). They supply the stress components without the factors P and $W_Q = \gamma \cdot W_s$ respectively. The factor γ was not included in the curves in order to make it possible to use values for γ that differ from the value used in this paper ($\gamma = 0.3$).

After the theoretical maximum stress in a new lamp design has been determined by means of Figs. 7 to 11 and the safety factor n according to equation (9) has been found, it is to be compared with the safety factors in established practical lamp types. For this purpose, the latter have been computed for several of the lamp types listed in Table I. The results are shown in Table II together with the working stresses found for these lamp designs. For most short arc lamps in spherical bulbs the safety factor n is in the same order of

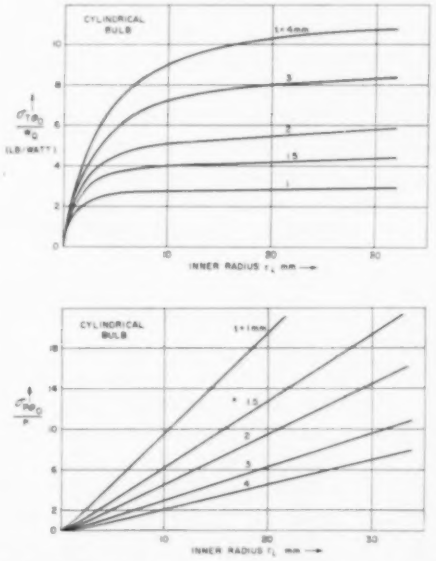

Figure 9. Cylindrical quartz bulbs: Tangential components of tensile and thermal stress at outer bulb wall as a function of inner bulb radius and wall thickness.

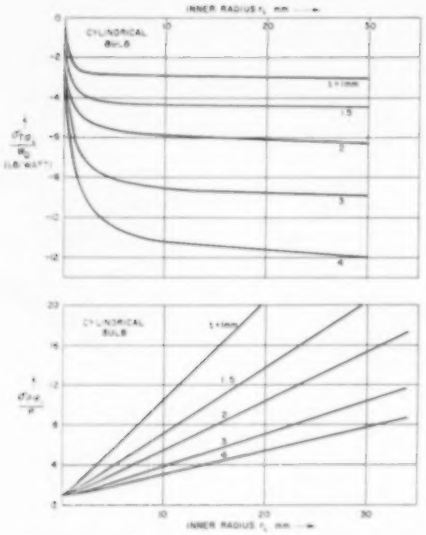

Figure 10. Cylindrical quartz bulbs: Tangential components of tensile and thermal stress at inner bulb wall as a function of inner bulb radius and wall thickness.

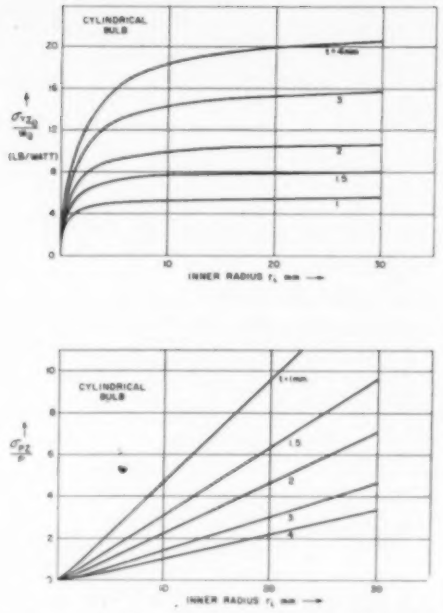

Figure 11. Cylindrical quartz bulbs: Axial component of the tensile stress σ_{PZ} and axial component of the thermal stress at the outer bulb wall σ_{TZ_o} as a function of inner bulb radius and wall thickness.

magnitude. In varies from 9 to 11.5 for the larger wattages and is around 13 for the small wattages. One exception is the lamp type No. 11 whose exceptionally large safety factor and small working stress could be explained by too low an estimate for the published operating pressure. These results lead to the assumption that a safety factor n between 9 and 13 may be considered adequate for operational reliability of short arc lamps in spherical bulbs.

The cylindrical water-cooled lamps (No. 19 and No. 21) have the much smaller theoretical safety factors of 2.3 and 3.8. These can be interpreted in different ways. Possibly, water-cooled lamps do not have to be as reliable in operation as spherical lamps without cooling because the water-jacket prevents serious damage in case of a failure. Another explanation would be that the actual reliability of these lamps is greater than indicated by the safety factors and that the method of calculation supplies too small values for n in the case of cylindrical lamps. The thermal stress components that contribute substantially to the high total working stresses may be lower in reality than indicated by the calculations. It may be a too great simplification to use the same value $\gamma = 0.3$ for short arc and for long arc lamps. In the latter type the electrode losses should contribute less energy to the heat conducted through the bulb wall than in short arc lamps.

The recommended method of determining the theoretical strength of lamp envelopes is based on the "maximum principal stress" theory. According to this theory, failure occurs when the maximum

TABLE II—Working Stresses and Theoretical Safety Factor in the Envelopes of Several High Brightness Discharge Lamp Types.

Type No. (See Table I)	P psi	$W_Q = 0.3 \times W_s$ Watts/sq. in.	r_i mm	t mm	$\sigma_{P\theta_o} + \sigma_{T\theta_o}$ psi	$\sigma_{PZ} + \sigma_{TZ_o}$ psi	$\sigma_{P\theta_i} + \sigma_{T\theta_i}$ psi	n
1	880	48	5.2	1.8	1100	——	1100	12.5
6	740	70	6.6	2.4	1080	——	480	13
10	510	45	13.0	3.0	1040	——	640	13.5
11	147	35	18.8	3.2	630	——	125	23
14	370	63	17.0	3.0	1340	——	580	10.5
16	370	60	22.8	3.2	1560	——	740	9
17	220	35	33.0	3.5	1220	——	640	11.5
18	290	66	24.0	3.5	1400	——	340	10
19	1100	1200	1.0	2.0	2850	6200	—4200	2.3
21	370	430	4.0	1.5	2500	3700	— 800	3.8

stress equals the ultimate strength of the material. It is generally assumed that the maximum-principal-stress theory best describes the behaviour of brittle materials like glass and fused quartz. Other theories, *e.g.*, the "maximum shear stress" theory, seem to be more suitable for ductile materials like metals.

As the equations (2), (3) and (6), (7) cover only the calculation of stresses for spherical and cylindrical bulbs, the question arises how the stress distribution in ellipsoidal envelopes can be determined. It is possible to develop mathematically correct equations for the stress components in ellipsoidal bulbs. However, for the purposes under discussion here, sufficiently accurate results can be obtained by replacing rather elongated ellipsoidal bulbs through cylinders of corresponding diameter. Relatively short ellipsoidal envelopes should be treated as if they were spheres with a diameter equal to the longer axis of the ellipsoid.

In general, the accuracy of the described numerical stress calculations is rather limited. Many simplifying assumptions are involved and some of the used material constants are not very well known. However, in spite of these limitations, qualitative and quantitative knowledge of the stress distribution seems to be useful for three purposes: (1) As a basis for quantitative comparison of existing lamp designs; (2) for interpreting test results with actually manufactured lamps; (3) for estimating the feasibility of projected new designs. The latter application can be of importance especially for the development of large wattage lamps. Such projects require well planned experimentation because of the great expenses involved.

Practical Strength of Complete Lamps

The "practical strength" of a complete high pressure lamp with sealed-in electrodes and leads may be substantially lower than the theoretical strength of the ideally shaped bulb determined by calculation.

Certain deviations from the ideal form of the envelope are unavoidable and may cause a concentration of stresses at particular points, *e.g.*, at the seals and at the exhaust tubulation. Inhomogeneities in the material, especially bubbles in the quartz, surface scratches, and thermal stresses remaining from the manufacturing processes are other reasons for reduced practical strength of a given lamp design.

The actual ability of a lamp to withstand a given internal pressure can be determined experimentally by subjecting it to a pressure test as described by Fig. 12. The lamp is connected to a high pressure gas tank through its exhaust tubulation by means

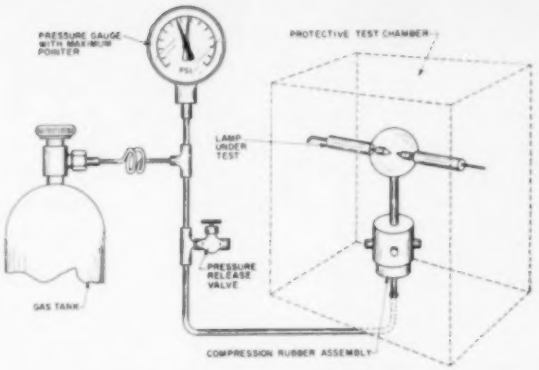

Figure 12. Pressure testing of high brightness discharge lamps.

of a compression rubber assembly as commonly used on lamp exhaust machines. If the valve of the gas tank is opened slowly, the pressure in the lamp can be raised to a certain test pressure or until fracture occurs. In the latter case the "bursting pressure" can be read from the maximum pointer of the pressure gauge.

This test method reproduces only the tensile stress condition in the lamp as caused by the internal pressure. It does not cover the additional thermal stresses appearing during lamp operation. In spite of this limitation, pressure testing of lamps is the best method of verifying the bulb strength calculations except operating larger numbers of finished lamps in life test.

The pressure test as described by Fig. 12 can also be used to advantage for testing the strength of lamps in the process of manufacture. The reliability of completed lamps can be increased considerably and production cost can be reduced, if faulty lamps with weak envelopes are summarily eliminated by a pressure test with sufficiently high pressure.

Estimating Feasibility of New Designs.

The practical design possibilities of certain types of high brightness lamps, especially of the water or air cooled capillary type, have proved to be very limited. However, it was difficult to understand clearly the reasons for these limitations. They can be explained satisfactorily on the basis of the particular stress condition in the bulb wall of such lamps.

Long arc lamps in narrow tubular envelopes with high bulb surface loading and forced cooling like the lamp types No. 19 and 21 listed in Tables I and II supply very useful elongated sources. They are capable of completely stable operation in horizontal position. However, the wattage per inch of arc

length and consequently the brightness of these lamp types have always been limited to relatively low values.

Certain applications definitely call for elongated sources with substantially higher brightness and wattage per inch arc length. Therefore, it has often been proposed to develop lamps similar to type No. 19 (Table I) but, for example, with three times its wattage per inch arc length. All attempts in this direction have failed so far, because of the steep increase of the thermal stresses with growing tube radius r_i. Figs. 9 and 11 show that σ_{TZ_0} and $\sigma_{T\vartheta_0}$ increase very quickly in the range of small tube radii up to approximately 4 mm, while the tensile stresses σ_{PZ} and $\sigma_{P\vartheta_0}$ grow only slowly within the same range.

It is, therefore, easy to understand that the allowable maximum stress is surpassed in capillary type lamps, as soon as the inner tube radius is essentially increased in order to sustain higher wattages per unit arc length without an increase in bulb surface loading. The steep increase of the thermal stresses within the range of small bulb radii explains also the well-known fact that it is difficult to obtain high wattage short arc lamps in small spherical bulbs with water-cooling. Such lamp designs would appear quite desirable for applications where the required forced cooling is no obstacle but where the reduced lamp cost due to the use of much the smaller bulbs would be of advantage.

As a last practical application of the stress calculations, the suitability of synthetic sapphire for the envelopes of high brightness lamps shall be discussed. Synthetic crystalline sapphire has been suggested[45] occasionally as an improvement over fused quartz because of its definitely higher melting point and its greater ability to withstand high operating temperatures over larger periods. It seems of interest to examine the properties of sapphire with respect to the size of the thermal stresses to be expected in a lamp envelope made of this material. The influence of the material constants on the thermal stresses is given by equation (8). The following numerical values were obtained for sapphire:[46] $\alpha = 90 \times 10^{-7}$; $E = 50 \times 10^6$; $\lambda = 0.26$ watts/degree C cm, $\mu = 0.16$. With these constants one finds $C = 2050$, while for quartz $C = 425$. This means that the thermal stresses in a sapphire lamp envelope will amount to approximately five times the stresses generated in a quartz envelope under equal conditions. However, the ultimate tensile strength of sapphire (40,000 to 65,000 psi according to the best available information) seems to be three to four and a half times greater than that of quartz. Thus, there is a good possibility that sapphire lamp envelopes could sustain approximately the same amount of thermal stress as quartz envelopes can hold.

Acknowledgements

Part of the material in this paper is taken from the author's doctor thesis accepted in 1952 by the Faculty of Mechanical and Electrical Engineering, Technical University Karlsruhe, West-Germany. The author is greatly indebted to Prof. Dr. P. Schulz, Director of the Illuminating Engineering Institute, Karlsruhe, and Prof. Dr. O. Reeb of the same institute for their advice and numerous discussions. The author is equally grateful for the encouragement given to him by management and engineering staff of Duro-Test Corp. The interest and assistance of Messrs. Cook, Cox, Strauss, and Thorington are especially appreciated. Mr. Strauss has also checked all calculations in the paper. Messrs. G. A. Freeman and M. C. Unglert, Westinghouse; Mr. T. S. Ainsworth, Siemens-Ediswan; Mr. E. Summerer, Osram; and Dr. O. Lienhard, Hanovia have kindly contributed lamp data and pictures.

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DISCUSSION

G. A. FREEMAN:* The paper is very interesting to people who have used short-arc mercury lamps and have been told to take precautions against possible violent failure. The mathematical analysis indicates a good factor of safety which for any structural device for resisting stress should be adequate.

There is one caution, however, that is very important and must not be overlooked. The mathematically determined factor of safety is based upon an average condition over the bulb surface. The area on the quartz glass bulb directly above the arc stream is subject to more heat than the rest of the bulb, due to the impingement of hot convection currents of the gas or vapor rising out of the arc inside the lamp. The condition here is not easy to calculate in terms of a factor of safety but experience with operation above rated wattage shows that the factor of safety vanishes all too quickly as the wattage loading is increased.

Analysis of broken bulbs after a violent failure has shown that once the inner bulb wall reaches the strain point temperature of the quartz glass, the effect is to put all the stress near the outer surface. The lamp may not immediately fail. While it may be impossible to measure the temperature of the inner wall, the result of such operation where the inner wall temperature exceeds the strain point can be detected in the strain pattern in the bulb wall after the lamp has been allowed to cool to room temperature even though violent failure has not yet occurred. Usually the strain is so severe in the bulb wall that violent failure occurs as the lamp is warming up in the next cycle of operation.

One might ask why not design the lamp with a still thicker wall to increase the factor of safety. When this was tried unsuccessfully it was analyzed in the manner of the calculations set forth in this paper. The heavier wall only increases the inner wall temperature so that the strain condition developed in the bulb wall from operation above the strain point of the glass occurs at even lower lamp loading than before.

In conclusion, it is of utmost importance to operate high pressure short-arc lamps within the wattage tolerances established by the lamp manufacturer or there will be very little factor of safety.

R. R. MATHESON:* Dr. Thouret is to be congratulated for a fine job of working out the calculations for probable stress levels in discharge arc tubes. Although the equations used in the calculations are well known to experts in the field, they are most likely new to this audience. Nothing would be gained here by reviewing the assumptions made to simplify these equations.

These calculations designate the general area in which the designer of a new lamp must start. However, the safety-factor idea for design should be examined more thoroughly. This safety factor should be correlated for each lamp type with respect to:

(1) Deviations of shape and wall distribution from the ideal cylinder or sphere.

(2) Surface damage normally incurred by the quartz in processing.

(3) Stress concentrations: (a) lead-in seals; (b) tubulation; (c) shape of ends; (d) thermal treatment.

(4) Deterioration of the quartz tube with lamp life, for example, devitrification.

(5) Possible transient stresses due to mounting-vibration combinations in use.

Dr. Thouret's work is an excellent beginning to the quantitative evaluation of the effects on strength of the practical parameters of fabrication and use.

S. M. SEGAL:** High pressure discharge lamps, meandering for several decades, now seem to be on the verge of a rapid acceleration into commercial and military importance. Dr. Thouret's paper, therefore, could not have been more timely. Furthermore, I consider his scientific approach a real contribution to the field and I hope that the base he has set will be expanded in the near future.

I was particularly interested in the additive stress factors at the outer wall of spherical envelopes as compared to the compensating compressive stress at the inner wall. It would seem desirable to develop an envelope of non-uniform consistency from inner to outer wall. Is it too radical a thought to hope that the glass industry, some time in the future, would be able to develop some type of graded wall, which, although more expensive to produce, would exhibit higher "ultimate strength"?

The pressure-testing method described by Dr. Thouret seems to have an undesirable feature in that an envelope would fail at a given pressure value, whereas it would have failed at a higher value if the compensating temperature stress were present. Tests to destruction, of this type, are expensive. However, it would seem that they would be worth the cost if they preceded a production job and if the temperature factor were included.

Studies toward optimum designs would be enhanced if it were possible to obtain high framing rate photographs of violent failures. The difficulty here would be that such cameras can only be operated for short periods of time. However, the following observations from personal experi-

*Westinghouse Electric Corp., Bloomfield, N. J.

*Glass Technology Laboratory, General Electric Co., Cleveland, Ohio.
**U. S. Army, Engineer Research and Development Laboratories, Fort Belvoir, Va.

ence are offered: In a number of violent failures during operation it was observed that a sudden and rapid change in the electrical indicators immediately *preceded* the failure. A camera could be triggered by such a rapid change in order that the weak point of the lamp could be disclosed photographically. As a point of added interest, it has been noted that some violent failures have occurred a few seconds after the lamp power had been cut off. In those cases it had not been ascertained whether the failures were due to rapid changes in envelope stress or to improper lamp mounting.

In a loaded question, for which I apologize in advance, I would like Dr. Thouret to venture a guess on what percentage of failures, in non-experimental lamps and omitting improper operation, have been due to localized imperfections in the quartz and seals rather than to the design?

There exists today some interest in obtaining high-wattage lamps (5 kw to 15 kw range) by building them in small spherical liquid-cooled envelopes. Dr. Thouret has pointed out that this is impractical and the reason for this seems obvious from the curves in Fig. 11, which indicate an extremely rapid rise in thermal stress with increasing inner bulb radius. However, the negative forecast is based on water cooling with a top temperature of 100C which creates too large a temperature differential between outer and inner walls. The question arises whether some progress in this application should be feasible if a higher boiling point liquid or a compressed high temperature gas cooling is used.

Finally, I suggest that, in the highly specialized field of rare-earth isotope purification, it may be possible to develop lamp envelope materials with more desirable characteristics than those of quartz or sapphire. I believe that this type of research should be supported.

W. E. THOURET:* Mr. Freeman and Mr. Matheson underline the fact that the presented stress calculations are based on relatively crude simplifications and that they only designate the general area of lamp dimensions where the designer of a new lamp must start. I certainly agree with both gentlemen. It would be very desirable to develop refinements by which the safety factor could take into account the practical deviations from the ideal bulb shape and the irregularities and inhomogeneities of the bulb material. I hope that in the future such improvements and refinements of the theory can be achieved.

Mr. Freeman is certainly right in stating that all calculations and the factor of safety lose their meaning when a lamp is operated above its rated wattage.

In reply to what Mr. Segal designates as a "loaded question," there are no apologies necessary because I think I can give a correct and complete answer in perfectly good conscience. As far as my memory and experience go, violent failures of non-experimental lamps are virtually always due to local imperfections, particularly irregular stress conditions, and similar reasons. Just the results of this paper show that such failures should not be attributed to faulty design because the manufactured lamp types seem to be designed with a sufficiently high safety factor.

Mr. Segal also asks whether the difficulties of making liquid-cooled lamps of higher wattage in larger envelopes could not be reduced by using liquids with a higher boiling point than water or by using forced air cooling. I think he is correct and, at least in theory, some progress could be made in the suggested manner.

*Author.

The Light Side of Beauty

A well-integrated combination of fluorescent and incandescent lamps produced an interesting lighting design in The Hairdo, a beauty parlor in El Cajon, Calif. For the desired effect, seven four-lamp, eight-foot fluorescent luminaires, equipped with 430-ma warm white deluxe slimline lamps, are ceiling mounted, and ten perforated-hood incandescent luminaires, each with one 60-watt lamp, are mounted on 24-inch stems. Maintained illumination level on work plane, situated beneath louvered fluorescent luminaires, is 100 fc while incandescent lighting provides nonactive dryer area with 35 fc. Data and photo courtesy San Diego Gas & Electric Co., San Diego.

Recommended Practice of Outdoor Parking Area Lighting

Prepared by the Subcommittee on Lighting of Service Stations and Parking Areas of the Store Lighting Committee of the Illuminating Engineering Society

Foreword

This Recommended Practice has been developed over the past five years. Its development began with the Store Lighting Committee's (now Merchandising Committee) request that the Roadway Lighting Committee prepare recommendations for the application of street lighting equipment to outdoor parking areas. As a result the Roadway Committee prepared a practice on parking area lighting. The Store Committee using these recommendations as a starting point prepared this Recommended Practice which treats parking area lighting from both street lighting and floodlighting approaches. Both W. H. Edman and M. E. Keck have served as liaison between the Roadway and Store Committees.

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1. Introduction

This Recommended Practice has been prepared as a guide to the application of fixed lighting to public and private parking areas of the outdoor type.

The adequate lighting of these parking areas is important from the standpoints of traffic safety, security, protection against thefts and vandalism, convenience and comfort to the user, and business attraction.

2. Illumination Requirements

2.1—*Basic Illumination Requirements*—(a) The minimum recommended illumination levels for the barest seeing essentials on the parking lot proper are as follows:

Type of Parking Area	Average Maintained Horizontal Footcandles
Self-parking area	1.0
Attendant parking area	2.0*

(b) Where additional lighting is desired for business attraction or customer convenience, values of five footcandles and upward are often used.

(c) Uniform illumination is desirable and the lowest footcandle value at any point on the pavement should not be less than one-fourth the recommended average.

(d) In parking areas dispensing gasoline, a minimum average illumination level of 20 footcandles is desirable in the service area around pump islands for safety and service requirements.

2.2—*Entrances and Exits*—The illumination levels at entrances, exits, loading zones, and collector lanes of parking areas should not be less than twice the illumination of the adjacent parking area or the adjoining street, whichever is greater.

3. Light Sources

3.1—*General*—Light sources used for the illumination of outdoor parking areas can be incandescent, mercury, fluorescent or any combination of the three. The choice of which to use is based upon economics, color of light desired and degree of light control required.

3.2—*Economics*—The owning and operating cost of the lighting system will depend upon many variables, such as: lamp cost, lamp life, burning hours, attendant luminaire cost, pole cost, type of layout, power cost, wiring and labor, as well as the amount of illumination required. It is recommended that the user check his requirements with someone well-versed in such costs in his locality in order to arrive at a comprehensive economic analysis.

3.3—*Color of Light*—The color of light delivered by the various types of sources makes little difference in seeing ability as long as the amount of illumination is the same. In the event that color differentiation is a problem, the light source should be selected in accordance with the specific application. Color rendition is quite different among incandescent, mercury, improved-color mercury and the various types of fluorescent lamps.

4. Types of Lighting Equipment

(a) A number of different types of luminaires are available for parking area lighting although floodlights or street lighting units are most commonly employed. The nature and shape of the parking area largely influences the selection of the specific lamp and luminaire combination best suited to achieve desired results. Both floodlighting and street lighting luminaires are optically designed to produce a specific distribution of light and the pattern produced is dependent on the size, location and type of light source used. Arbitrary changes in lamp source size, light center length, and outer bulb finish may radically alter this distribution.

(b) Floodlights are available in a wide range of light distributions from concentrating (for lighting areas at a distance) to wide spread (for lighting close-up areas), in symmetric, asymmetric and rectangular beam patterns to fit a large number of different requirements. Floodlights are available for use with many sizes of incandescent, mercury, fluorescent and reflectorized lamps.

(c) Floodlighting treatment varies in arrangement from a few high towers or buildings (40 to 100 feet high—probably used only for large areas) to a larger number of poles or building locations with lower mounting (20 to 40 feet high). In order to obtain coverage, including overlapping, various widths of beams are available as shown in Fig. 1(b) which can be projected in plan view to show the area covered. As a design aid in determining illumination levels and coverage isolux diagrams, curves showing illumination at various distances from the source, are often used. Appendix A shows examples of typical diagrams. Floodlighting has the advantage of flexibility of directional control when properly applied and can be directed to particular areas for coverage or for building up the lighting level in given areas for emphasis.

(d) Street lighting luminaires are available to accommodate incandescent, fluorescent and mercury lamps, and are designed to produce both symmetric and asymmetric light control. Here again narrow and wide patterns of light are available, as shown in Fig. 1(a), which can be projected in plan view to show the area covered. Appendix A shows examples of typical isolux curves. The spacing normal for good street lighting practice from a mounting height of 25 to 35 feet assures good coverage for uniformity of lighting, control of glare and a minimum of dense shadows.

(e) In applying both street lighting and floodlighting equipment, care should be taken to fit the area involved with the right pattern in order that the distribution is confined to the area to be lighted, and not permitted to spill over into neighborhood areas where it will cause glare.

5. Application

5.1—*General*—The application of lighting to outdoor parking areas should be given serious design consideration as it may contribute to the difference between a satisfactory and unsatisfactory operation.

5.2—*Basic Requirement*—The basic requirement in lighting an outdoor parking area is to provide good visibility with a minimum of glare. The most severe problem in such applications is to provide a measure of illumination in the many small, narrow "corridors" formed by adjacent parked cars. In order to get some light into these "corridors" it is rec-

*Higher illumination values are required for attendant parking lots than for self-parking lots because, with the former, closer parking, greater movement, and speed and accuracy of handling vehicles are important for greater monetary returns and avoidance of damage claims.

Approved by the Council of the Illuminating Engineering Society, September 1959. A Transaction of the IES.

ommended that any point in the entire parking area be provided with illumination from at least two, and preferably four, lighting (pole) locations with equipment mounted as high as possible, at a minimum of 20 feet. This method of lighting tends to reduce and soften shadows, lessens the possibility of objectionable glare and minimizes the effect of a temporary lamp burnout. The possible use of light-colored surfacing material, such as crushed limestone or granite chips, should not be overlooked as a good way to diffuse reflected light into hard-to-reach areas.

5.3 — *Luminaire Spacing* — The ratio of the luminaire (or pole, in the event of multiple-mounted luminaires) spacing to the mounting height should be kept to a minimum. For both floodlights and street lights a maximum spacing-to-mounting height ratio of 4 to 1 represents current good practice.

5.4—*Equipment*—The selection of lighting equipment having a proper light distribution is one of the essential factors in efficient and uniform parking area lighting. This will depend upon the luminaire spacing and mounting height, the amount of illumination required and the degree of uniformity desired. The multiple mounting of lighting units on each pole often permits a combination of more than one type of distribution which, together with individual horizontal and vertical angular adjustments (floodlights) allows maximum flexibility of design.

5.5 — *Pole Locations* — Lighting poles should be located generally along the parking barriers and outside boundaries. The placement of poles should present a minimum of obstruction to the movement and parking of cars. Where poles are located near automobiles the use of wheel barriers will save both cars and poles.

5.6—*Aiming*—Special care should be taken to avoid objectionable spill light and glare on adjacent property. This is best accomplished by aiming lighting units on near poles away from possible trouble spots and tilting down the facing units on other poles. A check on coverage and uniformity of such compromise installations will reveal the need for any additional lighting equipment that may be necessary due to the special aiming.

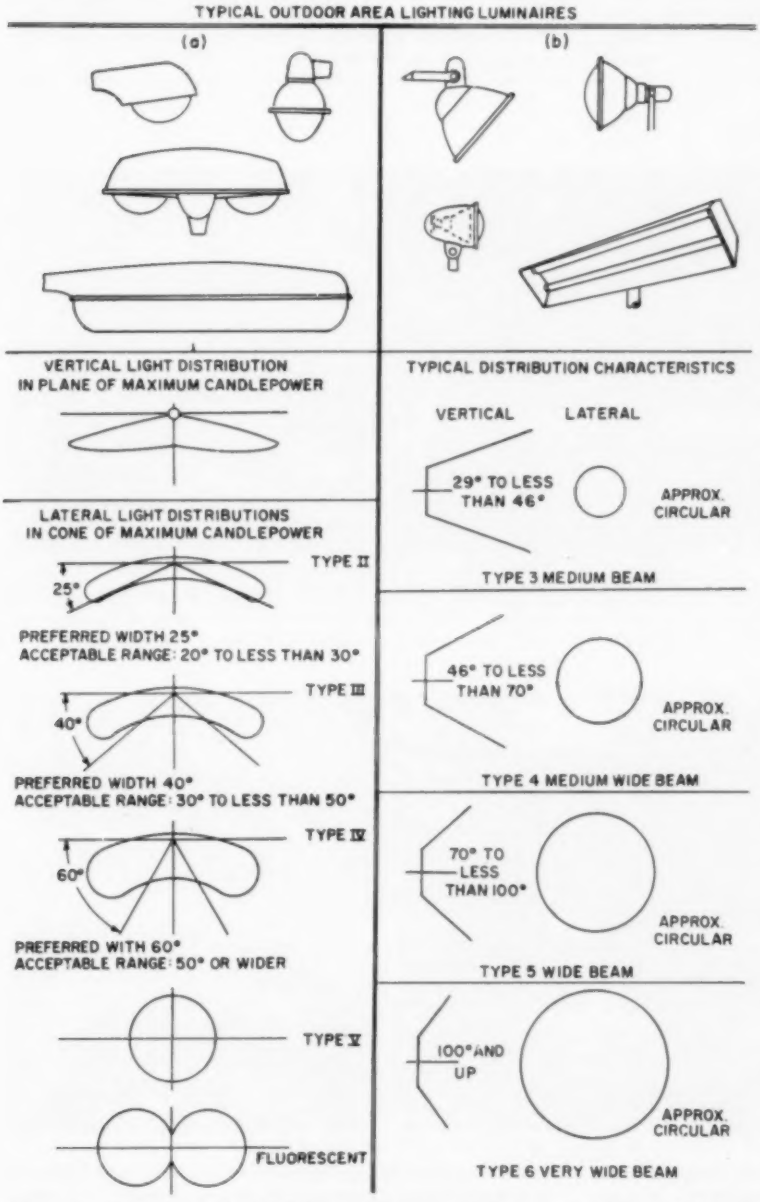


Figure 1. Street and floodlighting equipment used in parking area lighting.

6. Maintenance

(a) It is good practice to design a lighting installation with a "maintenance factor" to allow for the reduction in illumination normally expected due to lamp darkening (with use) and the collection of dust and dirt. The rate of lamp darkening depends upon the type and wattage of lamp used. Rate of dust and dirt collection depends upon type of lighting equipment involved. The maintenance factor consists of the mathematical product of these two components:

(1) *Lamp lumen depreciation component*—This value can be obtained from lamp manufacturers for the type and wattage of lamp being considered. When lamps are replaced individually (at burnout) or group replaced at a given per cent of lamp life the applicable mean lumen value should be used in determining this component.

(2) *Dirt collection component*—For "normal" dirt conditions:
Enclosed lighting units (all types)—80 per cent,

Figure 2. The parking area lighting system shown above uses 400-watt mercury lamps in street lighting luminaires which produce an IES Type III light distribution. Average illumination level provided by the system is 2.5 footcandles. Luminaire mounting height is 33 feet. Pole spacing is approximately 90 feet by 90 feet.

Figure 3. An average initial illumination level of 1.9 footcandles is produced at this Ohio shopping center parking area by street lighting luminaires which are equipped with 400-watt improved-color mercury lamps. Distribution pattern is IES Type IV. Mounting height of luminaires is 30 feet; pole spacing is 120 feet.

Figure 4. Four two-lamp fluorescent floodlighting units arranged in the pattern of a square provide an average initial illumination level of 2 footcandles in the parking area shown here. Luminaires are equipped with 72-inch T-12 high-output lamps and are mounted at 27 feet. Pole spacing is 100 feet.

Figure 5. Luminaires equipped with street lighting refractors and 400-watt mercury lamps are used to illuminate the parking lot in this Illinois shopping center. Mounting height for luminaires is 34 feet. Poles are spaced on 75-foot centers. The illumination level produced by the system is 4 footcandles.

Figure 6. An initial average level of 1.53 footcandles was provided in this Missouri shopping center by four-lamp street lighting units equipped with 72-inch T-12 cool white high-output fluorescent lamps. There are two per pole. Mounting height is 30 feet. Pole spacing is 100 feet by 110 feet.

Figure 7. Improved-color 400-watt mercury lamps in street lighting luminaires (IES Type IV distribution) are used to illuminate New York parking area. Mounting height, 30 feet. Pole spacing, 120 feet.

Figure 8. Five 16-inch floodlights on each pole are used to illuminate this parking area in an Ohio shopping center. Each floodlight is equipped with a 400-watt improved-color mercury lamp.

Open units (all types)—70 per cent. Where extremely dirty conditions exist these values should be decreased by an additional 10 to 15 per cent.

(b) Frequent cleaning will not only increase the average amount of illumination received but will increase life of lighting equipment as well.

(c) To facilitate maintenance there are available several types of lowering devices that permit equipment to be lowered to the ground for servicing. There are also several types of mobile equipment for maintaining luminaires in fixed position. (See the *IES Lighting Handbook*.*)

Appendix A—Isolux Diagrams

A line plotted on any appropriate set of coordinates which shows all the points on a surface where the illumination is the same as an isolux (iso-footcandle) line. When a series of such lines for various illumination levels are plotted on the same set of coordinates an isolux diagram is formed. Isolux diagrams for a few different types of luminaires, both street lighting and floodlighting, are shown below. In these examples the coordinates (horizontal distances on the surface to be lighted) are in feet. Other times they may be ratio of horizontal distances to mounting height.

By superimposing these diagrams on a proposed layout of a parking area drawn to the same scale, the approximate illumination level at a specific point may be determined. This is useful also in studying the uniformity of illumination that a particular lighting unit will provide in a particular arrangement.

It should be noted that the diagrams shown at right are for mounting heights of 30 feet only. For other mounting heights the footcandle values should be corrected by the factors shown. At the same time the coordinates should be changed in direct proportion to the change in mounting height. Footcandle values for luminaires with other size lamps may be obtained by increasing or decreasing values in direct proportion to light source lumen output.

For more information see Section 9, *IES Lighting Handbook*, 3rd Edition.

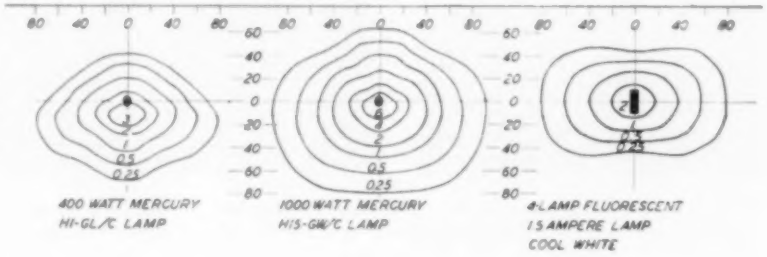
*Third Edition, pages 10-25 through 10-30.

TYPICAL ISOLUX DIAGRAMS
(INITIAL HORIZONTAL FOOTCANDLES)

MOUNTING HEIGHT: 30 FEET

FLOODLIGHT AIMING ANGLE - 45°

STREETLIGHTS

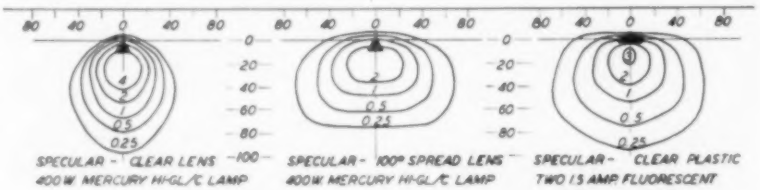


400 WATT MERCURY HI-GL/C LAMP

1000 WATT MERCURY HIS-GW/C LAMP

4-LAMP FLUORESCENT 1.5 AMPERE LAMP COOL WHITE

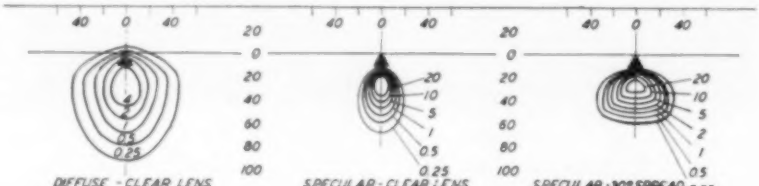
FLOODLIGHTS



SPECULAR - CLEAR LENS 400 W MERCURY HI-GL/C LAMP

SPECULAR - 100° SPREAD LENS 400 W MERCURY HI-GL/C LAMP

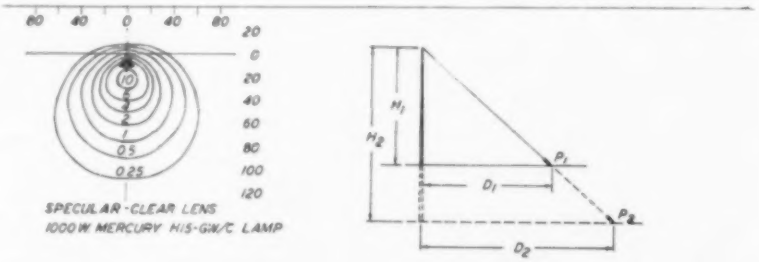
SPECULAR - CLEAR PLASTIC TWO 1.5 AMP FLUORESCENT LAMPS - COOL WHITE



DIFFUSE - CLEAR LENS TYPE 3 - 1000 W PS-52 CLEAR GENERAL SERVICE LAMP

SPECULAR - CLEAR LENS TYPE 3 - 1000 W PS-52 CLEAR GENERAL SERVICE LAMP

SPECULAR - 30° SPREAD LENS - 1000 W PS-52 CLEAR GENERAL SERVICE LAMP



SPECULAR - CLEAR LENS 1000 W MERCURY HIS-GW/C LAMP

MOUNTING HEIGHT	20	25	30	35	40	45	50	55	60
CORRECTION FACTOR	225	144	100	74	56	44	36	30	25

AS H_1 INCREASES TO H_2 THE ILLUMINATION AT POINT P_2 EQUALS $\frac{H_1^2}{H_2^2}$ X THE ILLUMINATION AT P_1

LIGHTING NEWS

Facts Behind IES Footcandle Recommendations Stressed at St. Louis Industry-Commerce Meeting

Assembling what may be one of the largest groups yet to hear the facts behind lighting research, its effects and results, the Union Electric Co. of St. Louis, with the co-sponsorship of the St. Louis Section of the Illuminating Engineering Society, presented a comprehensive program on "New Facts of Light" to an audience of 564 architects, engineers, contractors and representatives of commerce and industry. The dinner meeting, held March 16 at the Chase Hotel in St. Louis, presented three prominent IES and IERI personalities in a program which covered the background of the IERI study of illumination requirements and the benefits to be gained from the new IES recommended footcandle levels.

Speakers at the meeting included Hon. Raymond R. Tucker, Mayor of St. Louis and former head of the Department of Mechanical Engineering at Washington University; Professor Everett M. Strong of Cornell University, Chairman of the Research Executive Committee of IERI; C. L. Crouch, Technical Director of IES, and George J. Taylor, Vice-President of Research, Development and Marketing, Day-Brite Lighting, Inc.

Program was opened by Mayor Tucker, who welcomed the audience and emphasized the importance of the lighting developments which were to be discussed. Mr. Crouch presented a review of the laboratory research activities of Dr. H. R. Blackwell and his associates using projected illustrations of several practical seeing tasks. The need for minimizing direct and reflected glare to ensure maximum effectiveness of lighting was also emphasized by Mr. Crouch.

Mr. Taylor's presentation stressed the point that the footcandle values prescribed by IES are minimum, with higher levels of even greater benefit, especially for older people who do not have the visual acuity of the students used in the Blackwell observations. With the aid of charts and slides, Mr. Taylor demonstrated the practical benefits of modern lighting as compared to its cost and pictured numerous existing installations which already equal or exceed the IES footcandle recommendations. In conclusion, Mr. Taylor predicted that 100- to 1000-footcandle installations will become commonplace during the next ten years, to be followed, he felt, by even higher levels of light.

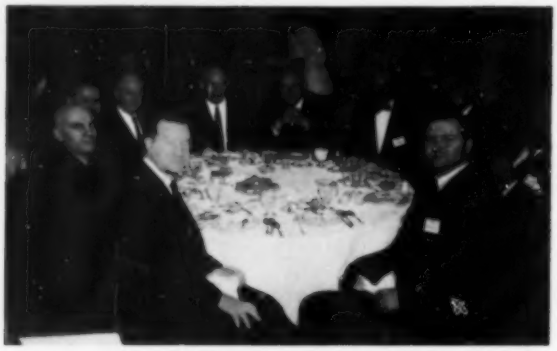
Merrill Skinner with C. L. Crouch

E. M. Strong and Brooks Chassaing

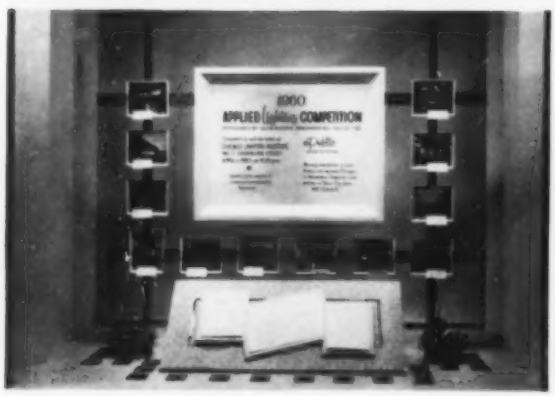
Some of the 564 people at "Facts of Light" meeting in St. Louis' Chase Hotel.

George J. Taylor, Willis Mangold

Head table (left) and some of the 75 guests representing a cross section of the lighting industry who gathered at stag dinner in honor of IES Past President, George J. Taylor, on the occasion of his move to St. Louis to assume new responsibilities with his company. Left to right at head table: B. F. Benning, Graybar Electric Co.; J. B. Browder, IES President; W. F. Keen, Chairman, Dinner Committee and New York Section, IES; George J. Taylor; H. S. Beagle, Electrical Testing Laboratories; Berlon Cooper, Associate Editor, *Electrical Construction & Maintenance*. The well-wishers presented Mr. Taylor with a movie camera as a farewell gift.



Dr. Robert S. Wiseman (right), Chief, Warfare Vision Branch, U. S. Army Engineer Research and Development Laboratories, Ft. Belvoir, Va., was honored with certificate and check for $300 for "Sustained Superior Performance." Colonel H. J. Skidmore, Director of the Laboratories, made the presentation. Dr. Wiseman, an active IES member and author of several papers presented before the Society, is currently chairman of the IES Design Practice Committee.



Local promotion by Chicago Section prior to its Applied Lighting Competition was this attractive, well-lighted window display featuring ALC entry forms (at bottom), framed panel with contest information and photographs of some of the contest entries. Display was in the window of a local utility building.

First-prize winner in Class II of Twin Ports Chapter's Applied Lighting Competition, Theodore Gunderson (left), shown here with his winning lighting design for a beauty parlor and contest judges, l. to r.: Harris Mahan, Herbert Spencer, John Damberg. Joseph Stuart, Belknap Electric Co., took first place honors in the residential contest.

Professor Strong concluded the symposium program with an explanation of IERI objectives, pinpointing the practical importance of various aspects of the Institute's researches. He stressed the importance of quality in lighting, comparing it to a high-fidelity system which has to have more than volume (footcandles) to be effective. In addition, Professor Strong reviewed several active IERI projects in other areas.

At the end of the meeting, P. W. McCormick, Industrial Sales Manager of Union Electric Co., who presided at the symposium, presented Merrill Skinner of Union Electric with an Award of Appreciation commemorating his co-founding 25 years ago of the Better Light Better Sight Bureau and his efforts in stimulating interest in and awareness of good lighting as a useful tool.

Assisting with the introductions of the speakers were Dudley Sanford, Executive Vice-President, Union Electric Co.; Brooks Chassaing, IES Midwestern Regional Vice-President; and Willis Mangold, Chairman, IES St. Louis Section.

Chicago Building Managers Attend Lighting Conference

Building managers' conference on office and building lighting was the feature presentation at the Chicago Lighting Institute last month. Talks by seven prominent speakers on such topics as the benefits of good lighting, problems of lighting and air conditioning and trends in office lighting were followed by an open panel discussion during which all speakers were available for questions from the audience.

Program schedule included:

Discussion Leader—James R. Sterling, Secretary, Building Managers Association of Chicago.

"Standard Lighting Fixtures" and "Adequate Lighting" — George R. Bailey, Building Planning Service, National Association of Building Owners and Managers.

What Is the Value of Adequate Lighting?— G. J. Taylor, Day-Brite Lighting, Inc., St. Louis, Mo.

Effects of New Lighting Levels on Heating and Air Conditioning Systems — Robert Geyer, Architectural Engineers, Commonwealth Edison Co., Chicago, Ill.

Color and Environmental Considerations in the Office—William Dunlap, Skidmore, Owings and Merrill, Architects.

Lighting Building Lobbies and Elevators—Albert Kurtzon, Alco Mfg. Co., Chicago, Ill.

Floodlight Your Building for Advertising Value —Benjamin S. Benson, Benjamin Division, Thomas Industries, Inc., Des Plaines, Ill.

Trends in Office Lighting Systems—George Gilleard, Curtis AllBrite Lighting, Inc., Chicago, Ill.

Panel — Moderator, George Fornero, Office Manager, Celotex Corp., Chicago, Ill.

The organizations which co-sponsored the meeting were the Building Managers Association of Chicago and the Chicago Lighting Institute.

Aviation Experts Meet at Atlantic City NAFEC For Briefing on Latest Ground Lighting Developments

Approximately 200 engineers and airline pilots gathered at the IES Aviation Ground Lighting Committee meeting at the Federal Aviation Agency National Aviation Facilities Experimental Center (NAFEC) in Atlantic City, N. J. on March 24 and 25 to inspect and discuss the latest systems of visual approach indicators, runway landing mat lighting, high speed taxiway lighting and weather bureau visual data appraisal.

The first morning of the two-day meeting was devoted to a description of the status of lighting developments for testing in the experimental approach and runway of the FAA facilities. L. C. Vipond of the Research and Development Division of FAA discussed the good and bad points of the narrow gauge runway landing lights including the Elfaka system, the MC-2 and the "button light." Following this, he traced the development of the unique "pancake light" as the successor to the various designs that have been in use up to the present time.

The pancake light, a flat light about the size of a pancake, is set flush in the pavement with a slight slope up to a hump in the center. Up and down the runway are wedge-shaped gouges in the casting, allowing the light to escape along the runway. At the central juncture of the gouges is the newly-developed quartz tubular bulb with iodide powder in the tube to give long life and high light output. A stainless steel strap covers the lamp assembly, protecting it from injury.

The pancake light is used down the center of the runway and, where a taxiway occurs, follows the center of the turnoff and taxiway. Thus, in perspective, the pilot sees an apparently continuous line of light down the runway and sweeping off into the taxiway. This permits him to maintain rather high speeds on the runway and turnoff and facilitates the landing of following aircraft.

Also described by Mr. Vipond was the use of floodlighting systems at the sides of the touchdown area of the runway. The beams of light from the floodlights sweep over the pavement at a near-to-grazing angle, enabling the pilot to see the texture of the pavement and get a "feeling" for the pavement location.

Following the descriptions of the experimental facilities, pictures were shown to demonstrate the effects the pilots see as they approach the runway and set the planes down.

Visual approach indicators used near the runway to show, by color coding, whether the pilot is approaching the field at the proper glide angle were discussed by Col. Richard Griffith. If the pilot is approaching too low, the lights show red; if he is on the glide path they show green, an alignment of green and amber or an alignment of white and amber; if he is too high the lights are amber, white or amber above green. Several systems are currently being tested by pilots at the NAFEC.

W. E. Eggert of the U. S. Weather Bureau presented a description of the rotating type ceilometer and automatic

(Continued on page 9A)

Photo: W. G. Osmun, Business/Commercial Aviation

AVIATION lighting experts forming panel at second day of Aviation Ground Lighting Committee meeting, left to right: R. J. Stefany, Chairman, IES Aviation Ground Lighting Committee; Dr. Dan Finch, University of California, inventor of prototype of "pancake light" (see story); R. K. McKelvey, National Aviation Facilities Experimental Center; Capt. E. A. Cuttrell, (former American Airlines pilot); Robert Gates, NAFEC; L. C. Vipond, Federal Aviation Agency; R. D. Hartz, Bureau of Aeronautics, U. S. Navy; A. E. Wallace, Wright Aeronautical Development Center; E. G. Rudberg, Office, Chief of Engineers, U. S. Army; Capt. R. A. Stone, United Airlines pilot, ALPA.

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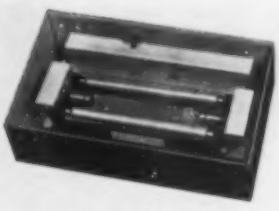

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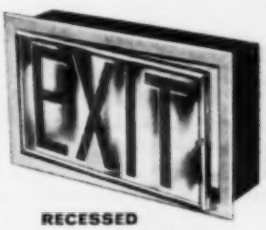

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(Continued from page 7A)

recording of ceiling height. He also showed tests set up for measuring transmission of the atmosphere along the runway and provisions for keeping the pilot informed, at all times, as to his visibility along a runway in fog conditions.

Following the morning technical sessions, delegates inspected the runway installation and the laboratory simulator used to pre-test lighting ideas. In the evening, the group was taken up in planes to observe the effects of the various lighting systems as they appear to a pilot.

The second morning of the meeting was highlighted by a panel discussion of aircraft ground lighting problems by experts representing the Federal Aviation Agency, Army, Navy, Air Force and Airline Pilots Association.

Photo: W. G. Osmun, Business/Commercial Aviation

PROFESSOR Dan Finch (stooping), inventor of prototype of "pancake light," points to installed "pancake" on runway during inspection tour of Federal Aviation Agency National Aviation Facilities Experimental Center in Atlantic City, N. J. At right is R. J. Stefany, Chairman of IES Aviation Ground Lighting Committee which sponsored the two-day meeting.

Fifth Electrical Industries Show Reported Largest to Date

Attendance reports from the Fifth National Electrical Industries Show, held in the New York City Coliseum in early March, indicate that over 22,000 people visited the show during its four-day run. International interest in the display (and in developments of the American electrical industry) was evidenced by visits from members of the British Consulate and Russian Embassy and daily broadcasts covering highlights of the show by the French, Italian and Yugoslavian Divisions of the Voice of America.

Organized around the theme of the development of electricity from 1880-1960, from Edison's first installation of electric current to today's production of electricity by atomic reactor, the show had 300 displays of new products and techniques developed by 180 manufacturers.

Armand D'Angelo, New York City Commissioner of Water Supply, Gas & Electricity, welcomed visitors at the opening session of the show, which was sponsored by the Eastern Electrical Wholesalers Association and produced by Harold R. Meyer and William S. Orkin.

HIGH-POWERED panel on "Illuminated Ceilings and Skylights" at Rocky Mountain Section meeting was manned by, left to right: Ray Carson, Construction Specialties; William C. Muchow, architect; Jim Watson, Fluorescent Maintenance Co., Walter Haller, technical sales engineer, Rohm & Haas Co.; Arthur Segil, New York sales manager, Luminous Ceilings, Inc.

Increase in Lighting Interest Seen in AIEE Activities

A technical session devoted to lighting at the Winter General Meeting of the American Institute of Electrical Engineers and the active program of the Illumination Division of the New York Section of AIEE are signs of a rising interest in illumination among electrical engineers.

The conference session, sponsored by the AIEE Production and Application of Light Committee, featured three technical papers, one an AIEE Transaction, the others, application papers. "Voltage-Temperature Life Testing of Fluorescent Ballast Insulation Systems," by C. A. Howlett, General Electric Co., Danville, Ill, was named a Transaction of AIEE; the other papers were "Integrated Lighting-Air Conditioning Systems" by W. S. Fisher, General Electric Co., Cleveland, and "Acceptance and Use of Higher Lighting Levels," by George Taylor, Day-Brite Lighting, Inc., St. Louis.

At a meeting of the lighting committee, following this technical program, steps were taken to reorganize the committee with the aim of expanding the scope of its activities to stimulate wider interest in illumination problems. Toward this objective several subcommittees on light sources, auxiliary equipment, lumi-

(Continued on page 10A)

(Continued from page 9A)

naires, street lighting, transportation lighting and general applications were organized.

The Illumination Division of the New York Section, under the chairmanship of Richard S. Wissoker, Day-Brite Lighting, Inc., has sponsored several lighting programs and a course, "Basic Considerations in Lighting Design." Recently members attended a program at the American Broadcasting Co. studios and heard a talk on "Studio Lighting Control by a Solid-State Device." This system uses a new semi-conductor dimmer with controlled rectifiers. Each luminaire, up to 300 in a studio, is equipped with one of these dimmers and a console in the studio control room provides simultaneous independent manual control of all circuits.

On April 28, the Illumination Division co-sponsored a meeting with the IES New York Section on the current state of lighting design in relation to architecture.

Photo: Berlon C. Cooper, Electrical Construction & Maintenance

FIVE new Sustaining Members from the New York Section, each representing a different branch of the lighting industry, were welcomed to IES at an informal reception held in Society Headquarters. Members of New York Section and Headquarters senior staff, serving as hosts for the party, were on hand to answer questions about IES activities and the sustaining membership program in particular. Seen here, left to right around table: John Churko, Section's Sustaining Membership Chairman; Harold J. Peters, Program Chairman; Anthony J. Scala, Lowy & Donnath (electrical contractors); Frank J. Walsh, consulting engineer; William H. Keen, Section Chairman; Paul Samberg, Arco Electric Co. (distributors); Fred Kasher, Spear Lighting Co. (manufacturer); W. F. Pedersen, Pedersen & Tilney (architects).

Success of Lighting Shows Prompts Texans to Plan '60 Exposition

The large attendance at and wide interest in the 1959 Lighting Exposition sponsored by the North Texas Section of IES (see December 1959 IE, page 12A) has encouraged the Section to schedule another lighting show, to be held in Dallas on November 4, 1960, under the chairmanship of E. R. Howard.

Designed to acquaint architects, electrical engineers, building managers and others concerned with the specification and maintenance of lighting systems with the latest developments in equipment and application, the exposition will feature exhibitions and demonstrations of new equipment for interior application. In addition, a prominent speaker will be present for an evening lecture on a topic of current interest in the lighting field.

The first exposition sponsored by the Section, in 1958, drew an attendance of 525; 1959's attendance exceeded that figure. As in past years, the show scheduled for 1960 has the approval of the IES Council Executive Committee.

Electrical Contacts Seminar Announced by Penn State

A six-day seminar dealing with theory and practice in the field of electrical contacts has been scheduled to begin on June 5 at The Pennsylvania State University, University Park, Pa.

Intended for practicing engineers, physicists and research scientists, the seminar will provide study and discussion of sliding, arcing and light-current contacts. Problems to be considered will include performance of silver contacts in silicone vapors, calculation of contact electrodynamic forces, methods of test of dry-circuit contacts and analysis of contact design.

Further information may be obtained from Ralph E. Armington, associate professor of electrical engineering, The Pennsylvania State University.

Quarterly Newspaper, "Engineer," Launched by Engineers Council

The Engineers Joint Council, a federation of 21 engineering societies, has begun publication of "Engineer," a newspaper designed to cut across specialty lines and present news of general interest to all members of the engineering profession.

First issue of the publication, a four-page paper, digests and interprets national news of particular concern to engineers and reports on the activities of the EJC. It also includes articles on problems of long-range interest to the profession, such as an impending future shortage of engineers and the current bright job outlook for engineering employees.

Financed by an allocation from membership dues to individual societies, the Spring issue of "Engineer" has been mailed to all members of the 21 societies within the continental United States. Further information on the new paper may be obtained from the Engineers Joint Council, 29 West 39th St., New York 18. The next issue is scheduled for June.

Design Engineering Show May 23-26, New York City

A glimpse of the future will be offered to an expected 20,000 visitors to the Design Engineering Show, an exposition devoted to research and development which opens on May 23 at the New York City Coliseum. Advance plans for the four-day show call for exhibition by more than 500 manufacturers of approximately 15,000 components used in the manufacture of end products for home and factory use.

Products to be shown include mechanical, electrical and electronic components, power transmission equipment, metallic and non-metallic materials, fasteners and adhesives, finishes and coatings, and shapes and forms. Also on display will be engineering equipment and services.

(Continued on page 13A)

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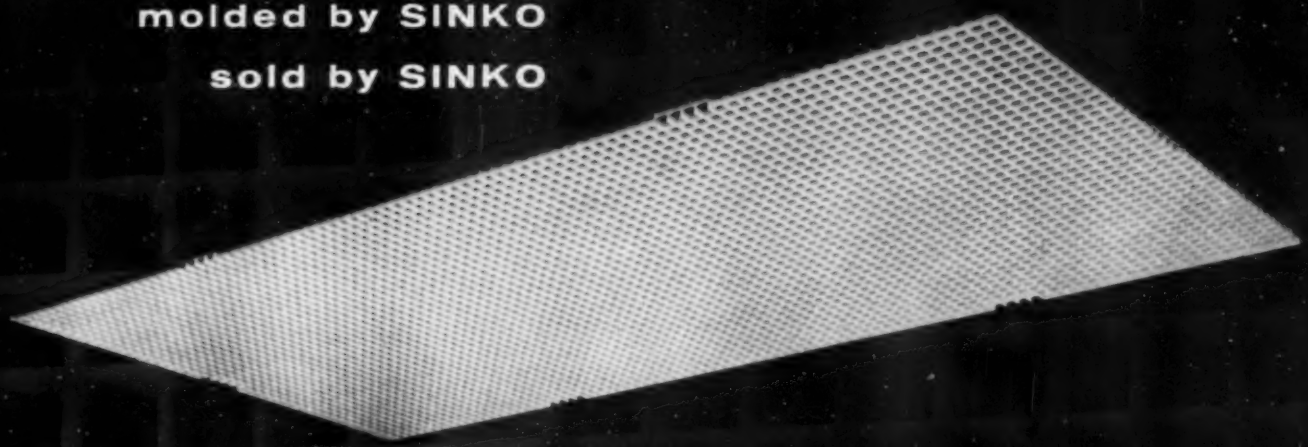

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Charter presentation to Gulf Coast Chapter, Mobile, Alabama, was made by J. M. Gensburger (second from right), South Central RVP, to Chairman Walton T. Reeves. Head table dignitaries looking on, from left to right: J. Dixon Mitchell, IES Director; G. R. Copeland, charter night chairman, and Henry R. Luscher, Mayor of Mobile, who gave welcoming address.

Gulf Coast Chapter officers installed by M. R. Hazzard, Chairman of "parent" Alabama Section, at Gulf Coast's Charter Night Meeting (see photo above) are, left to right: J. G. Pride, M. P. Ledbetter, E. M. Deupree, Hugh Byars, all members of Board of Managers; James Springer, Secretary-Treasurer; C. L. Thomas, Vice-Chairman, and Walton T. Reeves, Chairman.

Members of Milwaukee Section on tour of the Line Materials Industries, Inc., new high voltage laboratory in Franksville, Wis., hear George Manke, chief laboratory engineer for the company, explain the equipment and uses of the lab. On another Section outing, the Annual Extension Meeting, held during April, members toured several plants in the Beloit-Janesville area, after a dinner-business meeting at Lake Lawn Lodge in Delavan, Wis.

Faculty for 1959-1960 edition of Milwaukee Section's annual lighting course. Front row, l. to r.: W. C. Kuhnke, H. G. Williams, Jr., Ralph Cheney, Irving Illing, William Schumaker, R. L. Garber, R. J. Present. Back row: E. H. Schaefer, E. H. Grieb, A. B. Rowold, S. Gellman, Marshall Breusewitz, G. E. Dolan. Not shown: William Lowell, William Kennedy, Fred Williamson, Ray Eigner. Course had a registration of 48.

(*Continued from page* 10A)

Concurrent with the show, also at the Coliseum, will be a four-day conference sponsored by the machine design division of the American Society of Mechanical Engineers. Papers to be presented at the technical meeting will treat the application of space-age design theory and techniques to new consumer products. Advances in power, control, materials, computers, components and mechanics will be reported.

Street Lighting Standard Adopted By Sacramento County Ordinance

A recently-adopted county ordinance in Sacramento County, Calif., requires that all future street lighting installations in unincorporated areas meet or exceed recommendations contained in the IES-sponsored *American Standard Practice of Street and Highway Lighting*.

As a result of the law, citizens of Cheviot Hills, Calif. (a suburban, residential community) petitioned for a street lighting system which gives .23 footcandle of maintained illumination, exceeding the American Standard recommendation for streets with light pedestrian and vehicular traffic. The installation uses luminaires mounted on 25-foot-high poles on an average spacing of 185 feet staggered. Lamps are 6000- or 4000-lumen, depending on location.

ABOUT PEOPLE

Promotion of **Elio Rambaldi** to vice-president of the Perfeclite Co. was announced by Joseph L. Jaffe, Jr., president of the Cleveland concern. Formerly, Mr. Rambaldi had served the company as office manager and personnel manager.

The election of **Clarence C. Keller,** executive vice-president, Holophane Co., Inc., New York City, as chairman of the newly organized Lighting Equipment Division of the National Electrical Manufacturers Association has been announced by **Joseph F. Miller,** managing director of the Association. The Division, created in accordance with reorganization plans approved late last year, is comprised of the Aviation Ground Lighting, Floodlighting, Industrial and Commercial Lighting Equipment and Street Lighting Sections of NEMA. Members

(*Continued on page* 16A)

SCHEDULED EVENTS

May 22-26, 1960—National Office Management Association, 41st International Conference and International Office Exposition, Queen Elizabeth Hotel and Show-Mart, Montreal, Que.

May 23-26, 1960—Design Engineering Show, Coliseum, New York, N. Y.

June, 1960—Society of Plastics Engineers, Vinyl Plastics Meeting, Boston, Mass.

June 6-8, 1960—Edison Electric Institute, Annual Convention, Atlantic City, N. J.

June 8-9, 1960—Northeastern Regional Conference, IES, Wentworth-by-the-Sea, Portsmouth, N. H.

June 8-11, 1960—National Society of Professional Engineers, Annual Meeting, Statler Hotel, Boston, Mass.

June 10-26, 1960—British Exhibition (Industry, Technology, Science, Culture), New York City Coliseum, New York, N. Y.

June 12-15, 1960—American Society of Heating, Refrigerating and Air Conditioning Engineers, Annual Meeting, Vancouver, B. C.

June 13-14, 1960—Canadian Regional Conference, IES, Nova Scotian Hotel, Halifax, N. S.

June 16, 1960—Council Meeting, Illuminating Engineering Society, New York, N. Y. Members are free to attend meetings of Council as guests.

June 19-24, 1960—American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J.

June 20-24, 1960—American Society for Engineering Education, Annual Meeting, Purdue University, Lafayette, Ind.

June 27-29, 1960—Canadian Electrical Association, Annual Convention, Manoir Richelieu, Murray Bay, Quebec, P. Q.

August 8-12, 1960—American Institute of Electrical Engineers, Pacific General Meeting, El Cortez Hotel, San Diego, Calif.

August 22-24, 1960—National Association of Lighting Maintenance Contractors, Annual Convention, Milwaukee Inn, Milwaukee, Wis. All meetings are open to public.

September 6-16, 1960—Production Engineering Show, Navy Pier, Chicago, Ill.

September 10-18, 1960—Electrical Living Show, New York Coliseum, New York, N. Y.

September 11-16, 1960—Illuminating Engineering Society, National Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

September 21-23, 1960—American Society of Mechanical Engineers—American Institute of Electrical Engineers, Power Conference, Bellevue-Stratford, Philadelphia, Pa.

September 28-30, 1960—Canadian Electrical Manufacturers Association, Sheraton-Brock Hotel, Niagara Falls, Ont.

October, 1960—American Society for Engineering Education, Annual Meeting of North-Midwest Section, Marquette University, Milwaukee, Wis.

October 5-7, 1960—International Association of Electrical Leagues, Annual Meeting, President Hotel, Kansas City, Mo.

October 9-14, 1960—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 13-15, 1960—Optical Society of America Meeting, Somerset Hotel, Boston, Mass.

October 15-20, 1960—American Institute of Electrical Engineers, Fall General Meeting, Detroit, Mich.

October 16-22, 1960—Society of Motion Picture and Television Engineers, Semi-Annual Convention, Sheraton Park Hotel, Washington, D. C.

October 19, 1960—Society of Plastics Engineers, Tooling for the Plastics Industry, New York, N. Y.

October 23-27, 1960—National Electrical Contractors Association, Las Vegas, Nevada.

October 25-27, 1960—American Standards Association, National Conference on Standards, Sheraton-Atlantic Hotel, New York, N. Y.

November 14-18, 1960—National Electrical Manufacturers Association (Annual Meeting), Traymore Hotel, Atlantic City, N. J.

November 27-December 2, 1960—American Society of Mechanical Engineers, Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

November 29, 1960—American Institute of Consulting Engineers, Annual Dinner, Waldorf-Astoria Hotel, New York, N. Y.

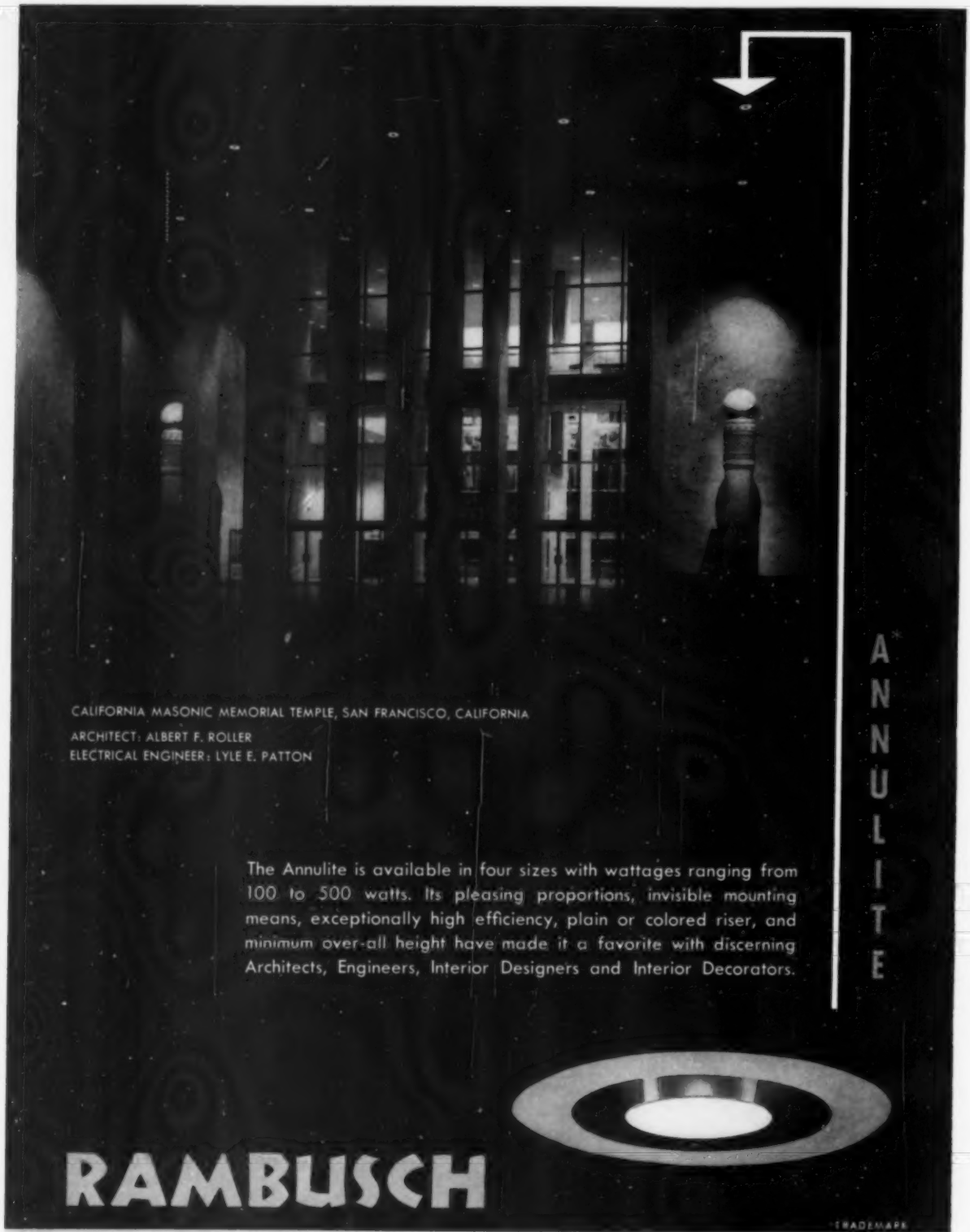
January 24-27, 1961—Society of Plastics Engineers, Inc., 17th Annual Technical Conference, Shoreham and Park Sheraton Hotels, Washington, D. C.

January 30-February 2, 1961—Plant Maintenance and Engineering Show, International Ampitheatre, Chicago, Ill.

February 13-16, 1961—American Society of Heating, Refrigerating and Air Conditioning Engineers, Semi-Annual Meeting, Conrad Hilton Hotel, Chicago, Ill.

Remaining 1960 Regional Conferences—IES

Region	Date and Place	Chairman
Northeastern	June 8-9 Wentworth-By The-Sea Portsmouth, N. H.	C. M. Holden Vorlander Lighting 80 Boylston St. Boston, Mass.
Canadian	June 13-14 Nova Scotian Hotel Halifax, N. S.	Henry Lushington Canadian G-E Co. Halifax, N. S.



CALIFORNIA MASONIC MEMORIAL TEMPLE, SAN FRANCISCO, CALIFORNIA
ARCHITECT: ALBERT F. ROLLER
ELECTRICAL ENGINEER: LYLE E. PATTON

The Annulite is available in four sizes with wattages ranging from 100 to 500 watts. Its pleasing proportions, invisible mounting means, exceptionally high efficiency, plain or colored riser, and minimum over-all height have made it a favorite with discerning Architects, Engineers, Interior Designers and Interior Decorators.

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LIGHTING

40 W. 13th STREET • NEW YORK 11, N. Y.

Even at 1000 to 1 odds...

YOU WOULDN'T MAKE A RED CENT

...on a bet like this!

If you installed 1,000 G-E Fluorescent Lamps and gave us $1 for every one that lit . . . and we gave you $1,000 for every one that didn't . . . chances are *the best you could do is break even!*

Those are pretty good odds—1,000 to 1. But if this bet is ever offered to you, don't take it. You wouldn't make a red cent!

BECAUSE G-E MONEY SAVER LAMPS ARE MORE UNIFORM—Test after test of production lamps proves that, on the average, *999 out of every 1,000 G-E Fluorescents will be good, right from the start.* (You might even *lose* money on the bet. Many users report G-E Lamp performance is even better than this!)

G-E FLUORESCENT LAMPS SAVE YOUR CUSTOMERS MONEY—Whether they buy a carton or a carload, the uniformity they get from General Electric Fluorescents—lamp after lamp after lamp—is their best assurance of getting the most light for their money. And this puts *you* in a very favorable light, too. Not only do they get 999 sure starters out of every 1,000 G-E Fluorescent Lamps they buy, but after almost two years 990 of these lamps will still be going strong! So they not only get more light, but their maintenance and production people like the freedom from annoyance and interruptions.

Performance like this stems from General Electric's constant search for new ways to improve *all* G-E Fluorescent Lamp types. Make sense? Then place your next order for lamps with your G-E Lamp distributor now—or write: General Electric Co., Large Lamp Dept. C-013, Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

GENERAL ELECTRIC . . . WHERE BRIGHT IDEAS BECOME BETTER LAMPS

(*Continued from page* 13A)

of the Division's Board of Directors, in addition to Mr. Keller, are: **E. B. Karns** (vice-chairman), Westinghouse Electric Corp.; **J. A. McDougall,** Revere Electric Manufacturing Co.; **K. C. Dorland,** Union Metal Manufacturing Co.; **J. Stanford Smith,** General Electric Co.; **A. C. Kendall,** Sylvania Lighting Products, Inc.

The American Home Lighting Institute, Chicago, Ill., has elected **Maurice M. Rosen,** president of Progress Manufacturing Co., Philadelphia, Pa., as president. Also elected were **Stanley A. Framburg,** H. A. Framburg & Co., Chicago, and **Max A. Shemer** of Esty Manufacturing Co., Chicago, as vice-presidents and **Ted Cox** of Ted Cox Associates, Chicago, as managing director.

The appointment of **Arthur C. Barr** to the Executive Committee of the Better Light Better Sight Bureau, New York City, has been announced by **Walter G. McKie,** general sales manager, Rochester Gas and Electric Corp. and chairman of the Bureau. Mr. Barr, who is manager of Product Planning and Development, General Electric Large Lamp Dept., Nela Park, succeeds **J. C. Forbes.** Other members of the Bureau Executive Committee are **J. T. Coatsworth,** Edison Electric Institute; **E. O. George,** Detroit Edison Co.; **L. P. Pleasants,** Sylvania Lighting Products; **H. E. Plishker,** Westinghouse Electric Corp. and **H. A. Stroud,** Monongahela Power Co.

Russell E. Ebersole, associated with the sales activities of the Westinghouse Lamp Division, Bloomfield, N. J., for nearly four decades, retired April 1 according to an announcement by F. M. Sloan, Westinghouse vice-president and general manager of the Lamp Division. This year marked Mr. Ebersole's 38th year with Westinghouse.

IES past president **Richard B. Brown, Jr.** was honored by his alma mater, Northeastern University, Boston, Mass., for an "outstanding record of professional achievement." The presentation was made by Asa S. Knowles, University president, on April 21, in ceremonies marking the 50th anniversary of the Cooperative Plan of Education and the founding of the College of Engineering.

On April 1 **Abbott L. Penniman, Jr.** retired as vice-president in charge of electric operations for the Baltimore Gas and Electric Co. Mr. Penniman had been associated with the company since 1911.

John E. Dawson has retired from the Public Lighting Commission of Detroit, Mich., after 40 years of service to the city. At the time of his retirement in February, Mr. Dawson served as Superintendent of Overhead Lines, Cable and Trouble Division.

A. D. Hinckley, IES managing director, served as one of the judges in the 1959 E. E. I. Sales Promotion Awards Competition, Commercial Market category. The two other judges for this competition were **C. A. Williams,** vice-president, United Illuminating Co. New Haven, Conn. and **George S. Jones,** managing director, Air-Conditioning and Refrigeration Institute, Washington, D. C. Presentation of the prize award plaques was made at the E. E. I. Annual Sales Conference, Edgewater Beach Hotel, Chicago, April 4-6.

The purchase of the Locust Lighting Co., St. Louis, Mo., has been announced by **Murray Reiter,** president of the Light & Power Utilities Corp., Memphis, Tenn. Acquisition of Locust, whose facilities and headquarters will be moved to Memphis, is part of Light & Power's planned diversification program within the lighting industry. An affiliate, Ceiling Materials Co., was announced last month.

Robert Gibson French has been named general sales manager of the Gibson Manufacturing Co., Atlanta, Ga. Mr. French, who will continue to maintain headquarters in Chicago for the time being, has previously operated sales agencies in Kansas City and Chicago. From 1948 to 1957 he served as general sales manager of the Steber Manufacturing Co., Broadview, Ill.

Merrill S. Sancraint has been promoted to manager of wholesale and utility sales of the Westinghouse Lamp Division. Mr. Sancraint, with offices in Bloomfield, N. J., will have special responsibility for lamp sales activities concerning utilities, rural electrification administration and primary wholesale distributors in electrical and hardware fields.

Thomas Industries Inc., Louisville, Ky., has announced the appointment of **Nelson Bleisch** as a merchandising manager at their Fort Atkinson (Wisconsin) plant. Mr. Bleisch, formerly a residential lighting adviser for the Union Lighting Co. in the St. Louis area, will be responsible for merchandising a division of the company's residential lighting lines. Also announced was the appointment of **Francis H. Delaney, Jr.** as office manager. Mr. Delaney, who was formerly connected with the Louisville & Nashville Railroad, will assist in the company's various personnel and industrial relations programs.

Kerrigan Iron Works Co., Nashville, Tenn., a subsidiary of Rockwell-Standard Corp., has announced a program of plant expansion and the addition of the following sales representatives: **Berry-Rochi, Inc.,** Long Island City, N. Y., to cover the New York City and Long Island area; **R. W. Mitscher Co., Inc.,** Buffalo, for New York State; Connecticut and southwest Massachusetts have been assigned to **Baynes, Inc.** of Hartford, Conn.; New Jersey to **P. M. Dreyfuss & Son** of New Shrewsbury, New Jersey; Michigan to **J. J. Gorman Co.,** Detroit; Virginia to **Charles C. Laney Agency** of Richmond and **C. D. White Co.,** Boston, Mass. will handle the New England states.

The appointment of **Myron E. Gerber** as Midwest regional sales manager has been announced by Halo Lighting Products, Inc., Chicago, Ill.

(*Continued on page* 31A)

I. E. S. National Technical Conferences

1960—September 11-16—Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961—September 24-29—Chase Park Plaza Hotel, St. Louis, Missouri

1962—September 9-14—Statler-Hilton Hotel, Dallas, Texas

1963—September 8-13—Sheraton-Cadillac Hotel, Detroit, Michigan

1964—August 30-September 3—Fontainbleau Hotel, Miami Beach, Florida

Gibson Fixtures Give You
More Than Good Lighting...
Much More!

ARCHITECT, MASTIN & SUMMER; ELECTRICAL ENGINEERS AND CONTRACTORS, CLEVELAND ELECTRIC COMPANY; GENERAL CONTRACTOR, IRA H. HARDIN COMPANY

GIBSON "PLUG-IN" FIXTURES SIMPLIFY MAINTENANCE FOR AMERICAN ART METALS

American Art Metals Company, Atlanta, uses Gibson fixtures with Power Groove lamps throughout its new plant. "We particularly like the ease of maintaining these fixtures," says E. L. McNiff, general works manager. "When a conventional fixture needs servicing, an electrician may spend half an hour or more up on a ladder to do the job. This distracts production workers. But when one of our Gibson fixtures needs attention, it is simply unplugged and another 'plugged-in' in its place—in the time it takes a man to climb a ladder."

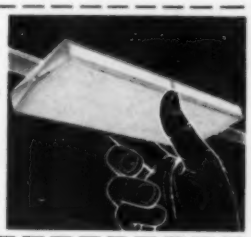
The exclusive "plug-in" feature of Gibson fixtures also offers substantial savings in installation costs and allows for re-spacing of fixtures and increasing lighting intensities any time without re-wiring.

Write for complete descriptive literature

GIBSON

Gibson LIGHTING

Makers of
THE FIXTURES
THAT JUST
"PLUG-IN"
PAT. PENDING



COMMERCIAL, TROFFERS, INDUSTRIAL

GIBSON MANUFACTURING COMPANY
1919 Piedmont Circle, N. E., Atlanta 9, Georgia

What more important single factor is there in an Art Museum, besides the paintings themselves, than the light to see them by?

EXTRU-LITE® SPECIFIED BY

AMERICAN LIGHTING CORP. FOR

SOLOMON R. GUGGENHEIM MUSEUM

DESIGNED BY

FRANK LLOYD WRIGHT

Frank Lloyd Wright designed the architecture to capture the daylight. Within the building, the fluorescent lighting cleverly blends with the natural light. Result: High level, glareless illumination . . . ideal for viewing art.

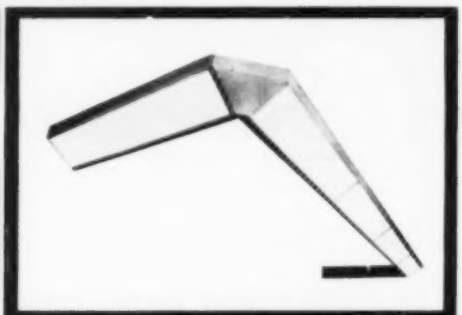
James Johnson Sweeney, Director of the Museum. Alfred Binder, Illuminating Engineer and Designer for American Lighting Corp., and A. E. Alper, Installation-Engineer of Daylight Elec. Construction Corp., are the men responsible for this tremendously effective lighting application. Much credit is due them for their new concepts of creation, courageous experimentation and zeal for perfection. That EXTRU-LITE was chosen is a tribute to its shielding excellence.

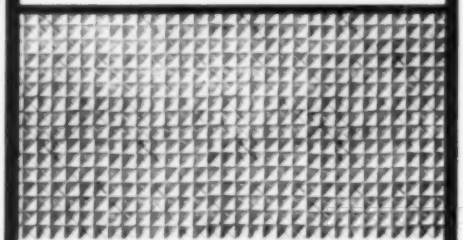
On the interior frontal ramp, 3-lamp fluorescent Luminaires are hung flush to the ceiling with the light source placed at an angle of abt. 40 degrees. The Luminaires form a U (see illus.) conforming to the gallery shape.

Each Luminaire uses 3 lamps. The ratio of illumination is approx. 2 to 1 in lumens — Cool White to Warm White. Crystal-clear EXTRU-LITE, (Rotuba's extruded plastic shield having over 9,000 prisms per sq. ft. and here made with Plexiglas®†) combines the 2 colors to achieve a diffuse, warm-enlivened light. Further, it gives brightness control with the desired illumination level in the viewing area.

Besides this highly publicized, highly specialized Museum job, Extru-Lite has been used successfully for over 5 years in thousands of installations, such as schools, banks, office buildings, hospitals and churches.

That's why we say, for the Best Buy in Sight
— Specify Fixtures using EXTRU-LITE.





Prismatic Extru-Lite is all plastic, either Polystyrene or Acrylic. It is tough, lightweight (approximately .6 lbs. per sq. ft. in ⅛" thickness), easy to clean, and safe to handle.

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MAKERS OF PLASTIC EXTRUSIONS FOR INDUSTRY

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Sylvania's NTWWS-2V28-RLM. One of Sylvania's complete line of Very High Output fixtures.

This fixture, with its wider 16" reflector, received immediate RLM approval, after testing, when the new RLM specifications for 1500 MA fixtures were announced.

Sylvania's broad line of Very High Output fixtures, using the powerful 1500 MA lamps, provides a *practical* and *economical* solution to a vast range of lighting problems.

Because they were designed to take full advantage of the tremendous light output of the 1500 MA lamp . . . and still maintain the features needed to control bothersome glare and brightness contrasts . . . Sylvania's Very High Output fixtures assure lighting *quality* to go along with the increased *quantity*.

And they cut down on initial costs, too, by saving 10¢ to 50¢ per square foot in the average installation.

Look into the advantages of using 1500 MA fixtures for *your* lighting. And be sure of getting *quantity* and *quality* by insisting on Sylvania's Very High Output fixtures.

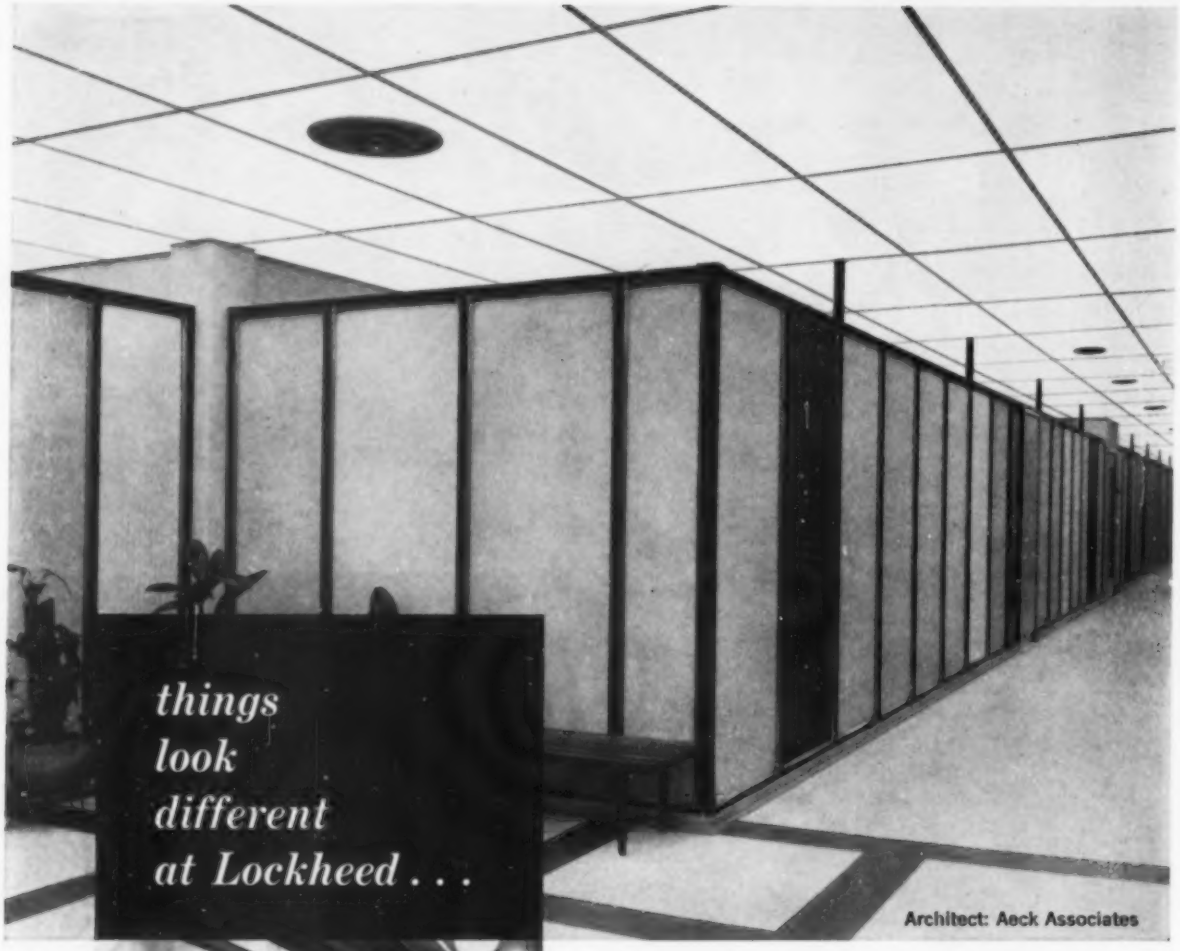
Complete technical and photometric information will gladly be sent to you upon request.

SYLVANIA LIGHTING PRODUCTS
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
One 48th Street, Wheeling, West Virginia

GO MODERN WITH LIGHTING BY **SYLVANIA**

Subsidiary of GENERAL TELEPHONE & ELECTRONICS

FLUORESCENT LIGHTING FIXTURES AND SYSTEMS • BEST FIXTURE VALUE IN EVERY PRICE RANGE



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Honeylite luminous ceilings played an important part in the striking modernization of Lockheed's Administration Offices at the Marietta, Georgia, plant. Made of durable Hexcel aluminum honeycomb, Honeylite delivers shadow-free, glare-free light into every corner of the working area below . . . at the same time enhances modern decor by concealing overhead pipes and duct-work.

Honeylite installation and maintenance are simple and inexpensive; a wide range of cell sizes, cut-off angles and finishes offers design flexibility to meet every lighting requirement. Honeylite's open-cell construction permits further cost savings when sprinkler, heating and air-conditioning systems can be integrated above the luminous ceiling.

In new construction or remodeling, versatile Honeylite can help you achieve any desired lighting effect. For complete information on Honeylite, today's most advanced luminous ceiling system, write Department H-5

HEXCEL® PRODUCTS INC.
World leader in honeycomb

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Distribution throughout the United States and Canada

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Keep your parks, playgrounds and playing fields in use after sundown ...with money-saving WIDE-LITES

Wide-Lites add hours of enjoyment every day to your recreational areas. With their exclusive rectangular reflectors, Wide-Lites give a broad, even light pattern that is essential to eliminate "hot spots" and shadows from playing fields.

Each Wide-Lite with color-corrected mercury vapor lamp will do the work of *two* or *more* incandescent floodlights—reducing the required number of poles, crossarms and fixtures. And operating on 460 volts, Wide-Lites require 50% less transformer capacity, with smaller conductor wires. Wide-Lites make practical low-cost underground wiring for floodlights!

Find out how much better lighting you can get with Wide-Lites—and how much less it costs! Send the coupon today.

Resists vandalism! Wide-Lites are made of rugged cast aluminum and have tempered glass lenses to resist vandalism and the punishment that floodlights get from wind and weather. Relamping is easy, but with 7000-hour lamp life (seven times as long as incandescent), it's seldom needed!

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OUTDOOR AREA LIGHTS · VAPOR TITE MODELS · INDOOR LUMINAIRES
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Please send me more information on Wide-Lites. No obligation, of course.

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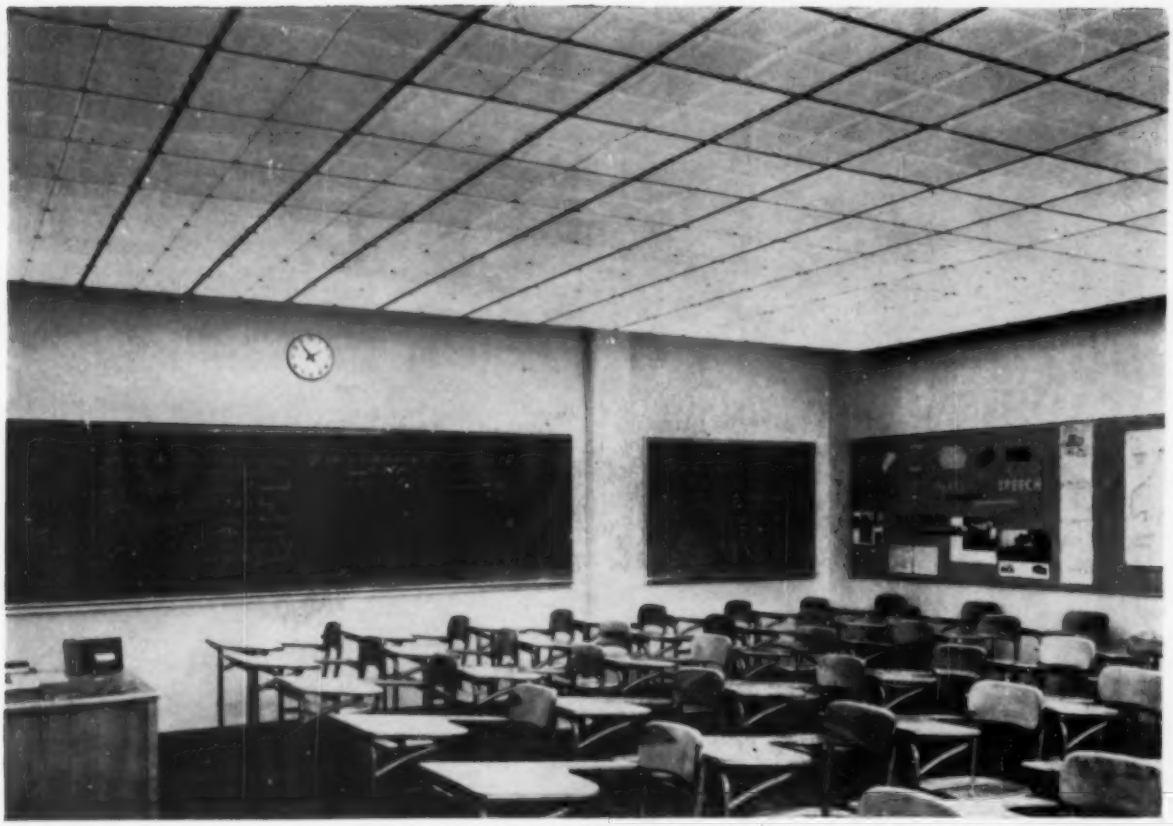

SCHOOL STAFF ENTHUSIASTIC! Shadow-free light, the equivalent of soft daylight, achieved at low cost with translucent ceiling. (Min. 50 f.c. uniform intensity, max. brightness ratio under 3:1.) All structural members concealed. Nearly all rooms in the De Anza High School, El Sobrante, Calif., rely entirely on this lighting. Designed by John Carl Warnecke, AIA. "Acousti-Lux" panels and suspension system by the Celotex Corporation, Chicago, Ill.

Lighted by translucent ceiling...

This classroom needs no windows!

Night or day, cloudy or sunny, this classroom is evenly lighted. No problems of balancing daylight against illumination . . . no dark shadows—a more cheerful atmosphere . . . and figures indicate operating costs lower than many other systems! Translucent ceilings made with BAKELITE Brand Rigid Vinyl Sheet give complete control over lighting characteristics—and can help acoustically, too.

NOW . . . HIGH IMPACT RESISTANCE! BAKELITE rigid vinyl sheet is now available with *new high impact qualities* giving extra resistance to the hard knocks, the wear and tear of installation and maintenance. It resists cracking and warping . . . is normally unaffected by moisture or detergents. The lightweight panels are easy to install or remove, and to maintain. They are highly resistant to discoloration caused by ultraviolet light.

New lighting designs, renovations—they will look better, serve longer when you install luminous ceilings made with *high-impact* BAKELITE rigid vinyl sheet. For more information, write Dept. BB-72, Union Carbide Plastics Company, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

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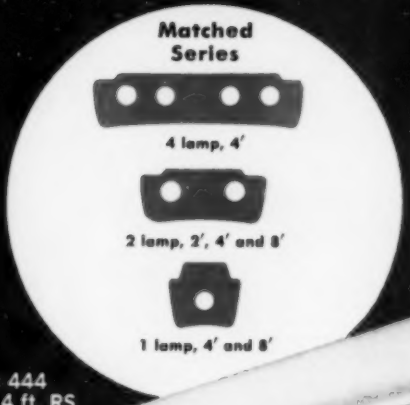
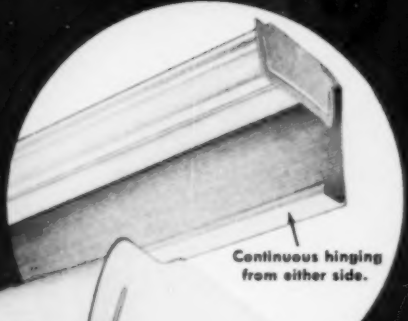
New Gar-Lite Dualens Series*





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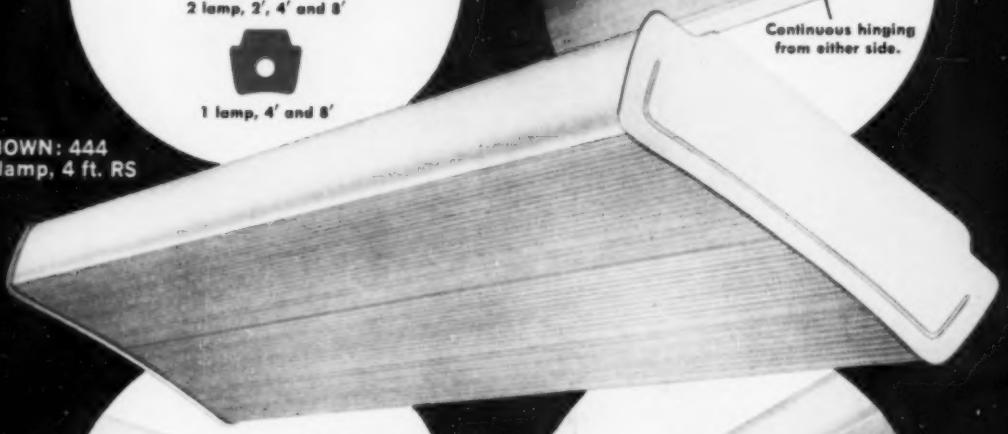
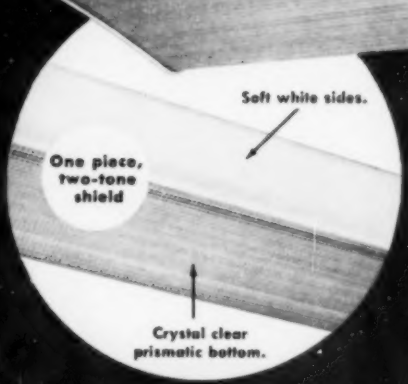
Four-lamp, 4 ft. RS



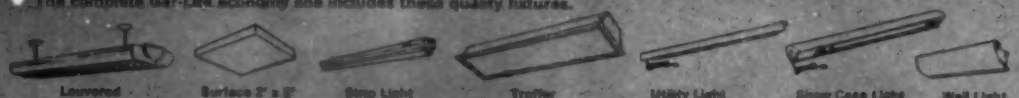


Sensibly priced lighting with matched series versatility

Don't overlook the new Gar-Lite Dualens Series. No other low priced, top quality fixture can offer you this matched series versatility — six fixtures, in lengths and lamps to meet every requirement.

And it's hard to equal the many exclusive built-in features found in the Dualens Series . . . features seldom found even in higher priced fixtures.

* The complete Gar-Lite economy line includes these quality fixtures.



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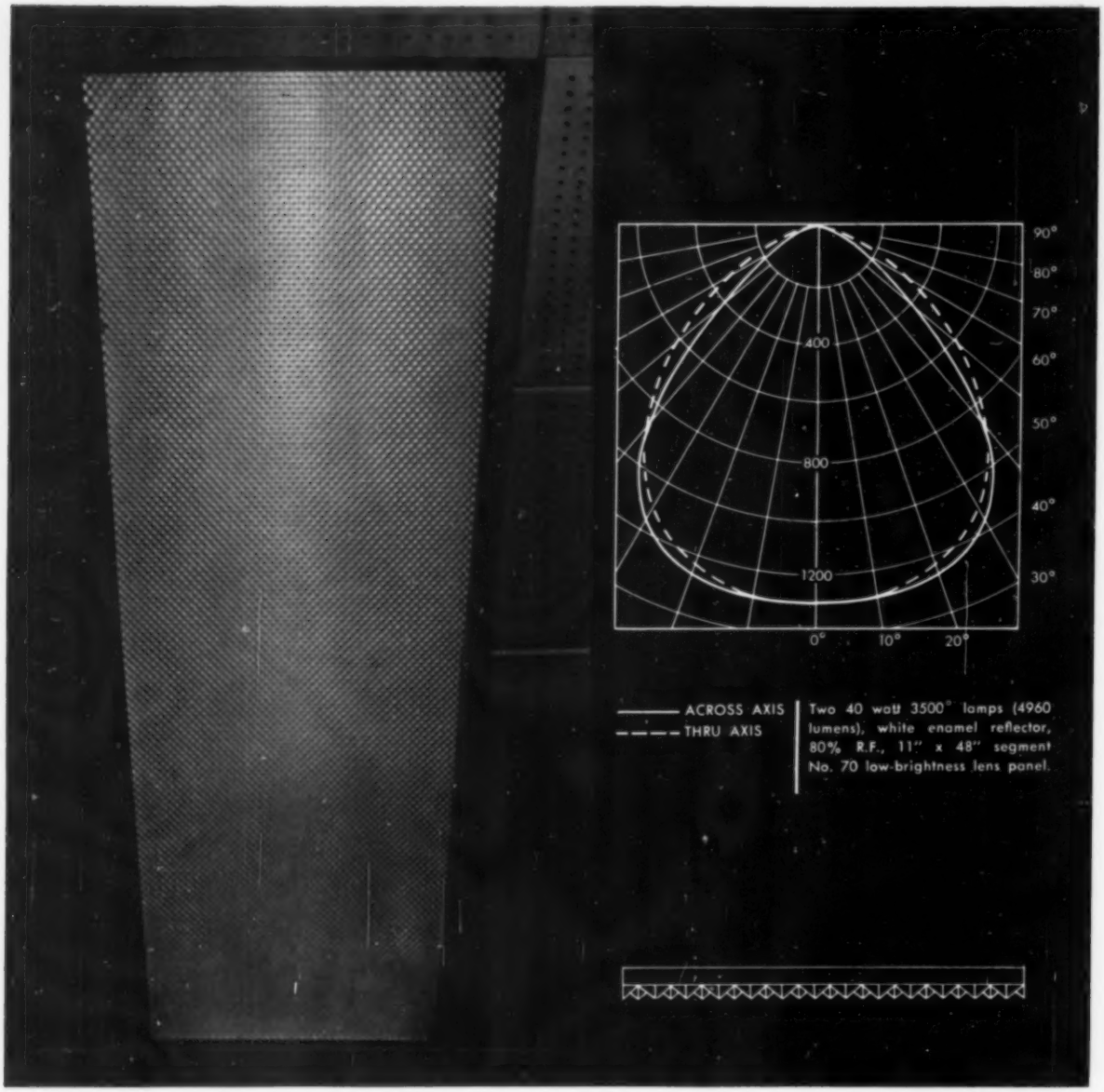
2475 Elston • Chicago 47, Ill.

Write for your Gar-Lite brochure today.



Some things you should know about this low-brightness lens panel

This is Corning's Crystal No. 70, a prismatic lens panel with very low surface brightness in the direct glare zone. It is designed to deliver maximum illumination in *useful* directions.

Because it's *glass*, it won't warp, sag, bend. It can't discolor; cleans easily, doesn't attract dust.

The water-white crystal composition assures maximum transmission of light without color distortion. It is available $\frac{1}{8}$" thick annealed, or ¼" thick annealed or tempered in single-panel sizes up to eight square feet in area.

Crystal No. 70 is recommended for areas where high levels of illumination and maximum brightness control are desired: general offices, classrooms, hard-goods sales areas in stores, luminous ceilings and large-area luminaire applications.

For complete data on performance and designs of Crystal No. 70 and other lighting glassware, write Lighting Sales Department, 61 Crystal Street, Corning, N. Y.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

This modern design troffer — only 4⅞" deep — permits reduction of plenum depth — offers additional structural freedom between floors. Engineered to Benjamin's nationally-recognized quality standard, this new shallow-line troffer has been performance tested in the Benjamin lighting fixture laboratory.

Five basic sizes provide complete versatility — 2'x 4', 2'x 8', 1'x 4', 1'x 8' and 2'x 2'. The most complete selection of lenses or louvers in the lighting industry provides a type to meet every requirement.

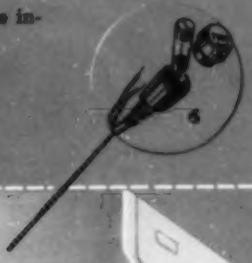
A Benjamin lighting sales engineer is always available to help you with your lighting plans.

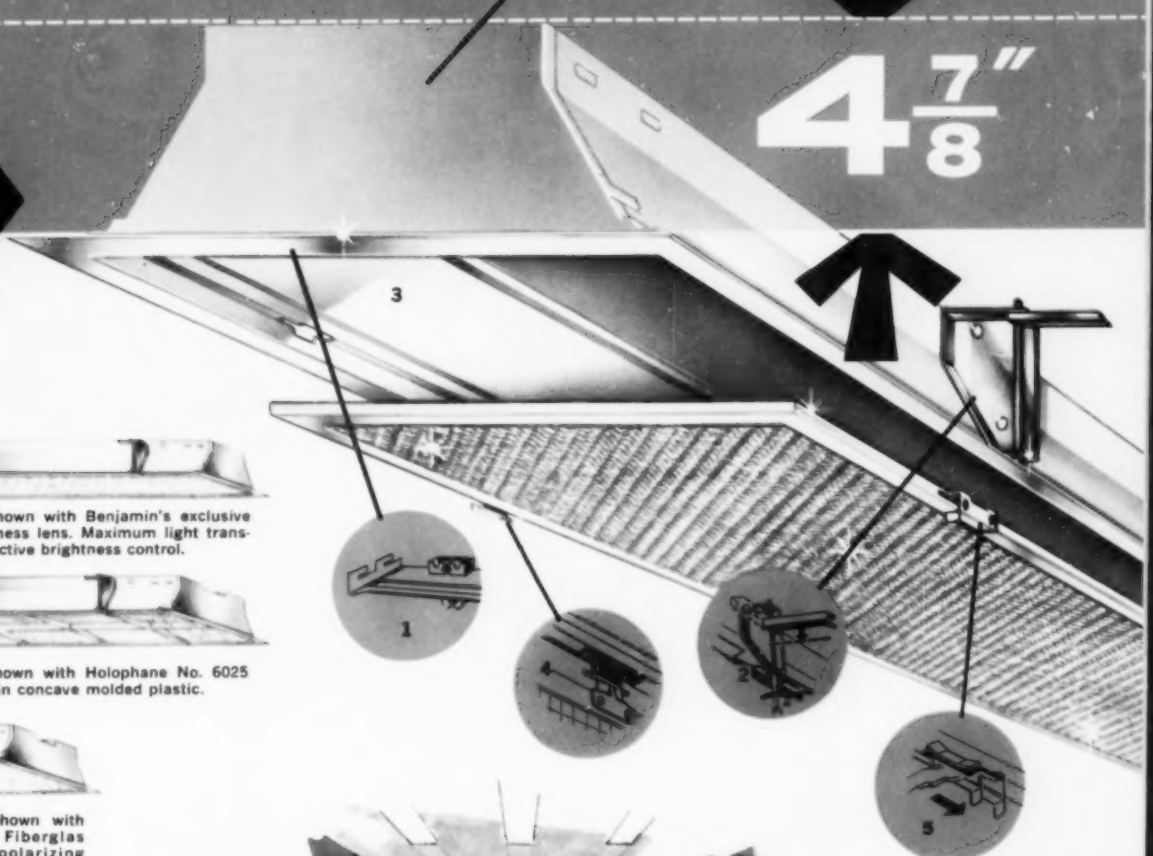
1. **NEW SNAP-IN SOCKET** — simplifies installation — locks in firmly, eliminates vibrations.
2. **NEW SWIVEL SUSPENSION** — quick installing swivel bar mechanism cuts labor time and cost. ¼ turn of 4 screws suspends unit.
3. **NEW ONE PIECE HOUSING** — unitized 4' and 8' fixtures possess maximum structural strength.
4. **SUPERIOR HINGING MECHANISM** — so simple it merely drops into place — no screws to tighten.
5. **UNEQUALLED TAB-LOCK LATCH** — provides easy, positive action, gives permanent rattle free fastening.
6. **PROTECTED AGAINST OVERLOAD** — cartridge fuse installed in every unit as added safety feature.

NEW FROM BENJAMIN

THE WORLD'S MOST COMPLETE LINE OF ARCHITECTURALLY ENGINEERED

SHALLOW-LINE TROFFERS





1' x 4' Troffer, shown with Benjamin's exclusive L-120 low brightness lens. Maximum light transmission plus effective brightness control.

2' x 4' Troffer, shown with Holophane No. 6025 Lens. The finest in concave molded plastic.

2' x 2' Troffer, shown with Owens Corning Fiberglas Lens. New flat polarizing light diffusing panel, reinforced with fiberglas flake.

BENJAMIN DIVISION
Des Plaines, Illinois
THOMAS INDUSTRIES Inc.
World's Largest Single Source of Lighting for Home, Commerce, and Industry.

SEND FOR THIS NEW 52 PAGE CATALOG — gives complete technical information and specifications on Shallow-Line Troffers. Request Bulletin A: Benjamin Division, Thomas Industries Inc., Louisville 2, Kentucky, Dept. 4C.

The Benjamin *Lumi-Flo* is a completely unique recessed LIGHTING troffer, designed for direct connection to HEATING and/or AIR CONDITIONING. Positive proof of its performance and outstanding appearance is provided by hundreds of installations. *Lumi-Flo* employs the low velocity principle of air handling, introducing air straight down into the room. Drafts are eliminated — hot and cold spots are overcome — lighting efficiency is substantially increased.

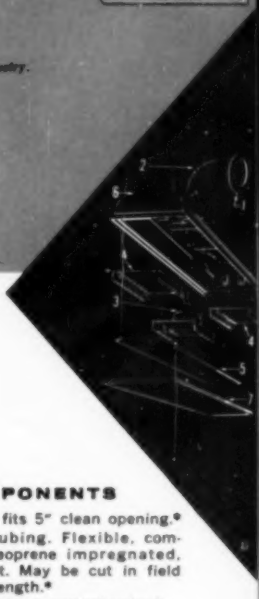
Because of its superior engineering and exceptional features, *Lumi-Flo* requires fewer ceiling openings, eliminates unsightly air diffusers and becomes a handsome, functional part of a completely integrated design.

Lumi-Flo also offers you totally new freedom in designing room interiors, since its air distribution is not dependent on walls or partitions. Consequently, modern modular units may now be planned with complete freedom of partition arrangement. A complete selection of closures are available in prismatic lens or louvered types. Simplified installation insures important savings in time and labor costs.

WRITE FOR NEW LUMI-FLO CATALOG — Bulletin B contains complete specifications and installation information. FREE on request from Benjamin Division, Thomas Industries Inc., Louisville 2, Ky., Dept. 4C.

BENJAMIN DIVISION
Des Plaines, Illinois
THOMAS INDUSTRIES Inc.
World's Largest Single Source of Lighting for Home, Commerce, and Industry.

the most advanced design in the commercial field



Benjamin LUMI-FLO 3-IN-1 TROFFERS

COMPONENTS

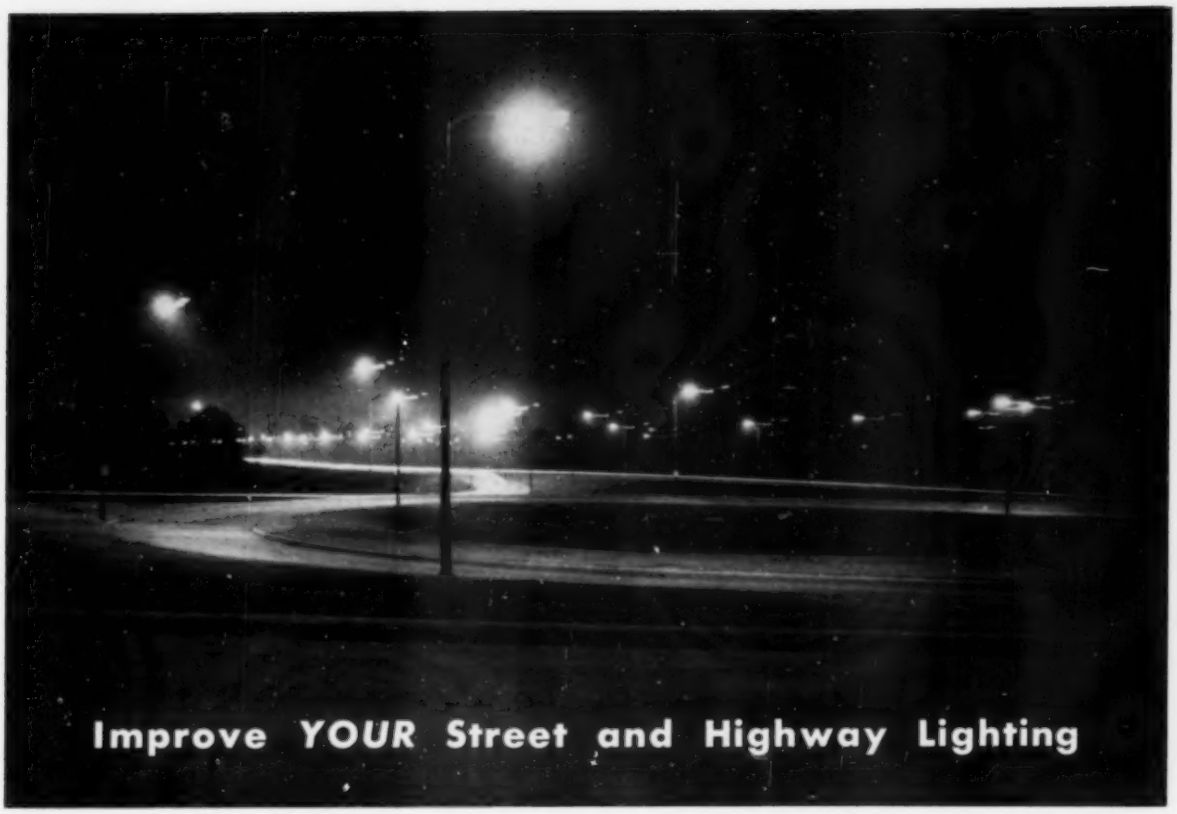
1. Duct collar, fits 5" clean opening.*
2. Fiberglass tubing. Flexible, compressible, neoprene impregnated, fire-retardant. May be cut in field to suitable length.*
3. Adjustable volume control valve.*
4. Diffusing plate.
5. Inner reflector.
6. Troffer housing.
7. Shielding element.

**Supplied by sheet metal contractor.*

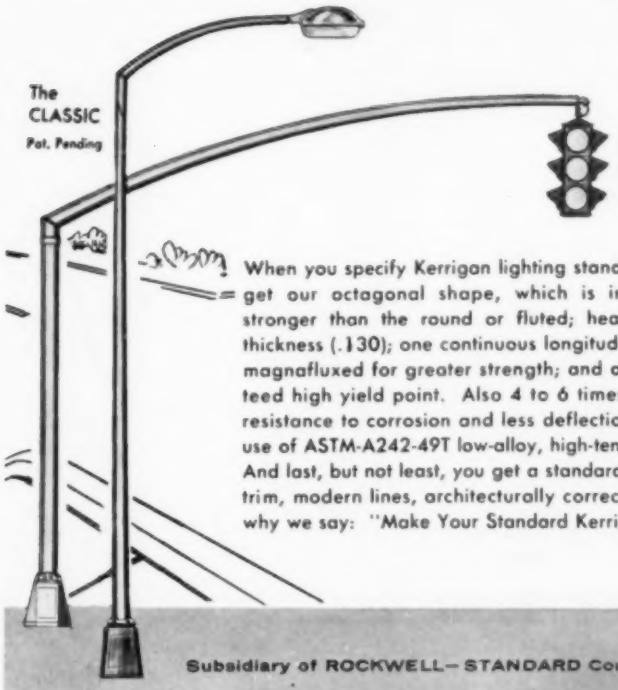
PROVED AT THE HARRIS TRUST & SAVINGS BANK, Chicago, Illinois
. . . and in hundreds of other installations, including:

STATE SERVICES BUILDING, Denver, Colorado
PARKE-DAVIS BUILDING, Ann Arbor, Michigan
STATE OFFICE BUILDING, Indianapolis, Indiana
I. B. M. CORPORATION, Endicott, New York
WESTERN ELECTRIC CO., Allentown, Pennsylvania
UPJOHN COMPANY Menlo Park, California
GEORGIA POWER CO., Atlanta, Georgia
THE BANK OF CALIFORNIA Berkeley, California
FIDELITY CASUALTY INSURANCE CO., Jacksonville, Florida

U.L. Listed for Lighting, Heating, Cooling



MAKE YOUR *STANDARD* KERRIGAN



When you specify Kerrigan lighting standards you get our octagonal shape, which is inherently stronger than the round or fluted; heavier wall thickness (.130); one continuous longitudinal weld magnafluxed for greater strength; and a guaranteed high yield point. Also 4 to 6 times greater resistance to corrosion and less deflection by our use of ASTM-A242-49T low-alloy, high-tensile steel. And last, but not least, you get a standard that has trim, modern lines, architecturally correct. That's why we say: "Make Your Standard Kerrigan!"

Our new 70-page catalog has the engineering facts on both steel and aluminum standards! Won't you write for your FREE copy now? Address: Dep't. I-S.

KERRIGAN
IRON WORKS COMPANY
Nashville, Tennessee

Subsidiary of ROCKWELL—STANDARD Corporation

the latest lighting advancement from...

APPLETON®
electric company

first

lighting unit to give you top operating performance from the amazing Quartzline lamp!

Intenso. "QUARTZLITE 500"

Only the Appleton *Intenso* "Quartzlite 500" is precision engineered to meet the lamp manufacturer's efficiency and operating standards for the new 500-watt, filament type, iodine cycle lamp.

Its new, compact design was specially developed for this powerful lamp to give you 19% greater, *constant* light output of 21 lumens per watt . . . and twice the average life of a conventional 500-watt lamp.

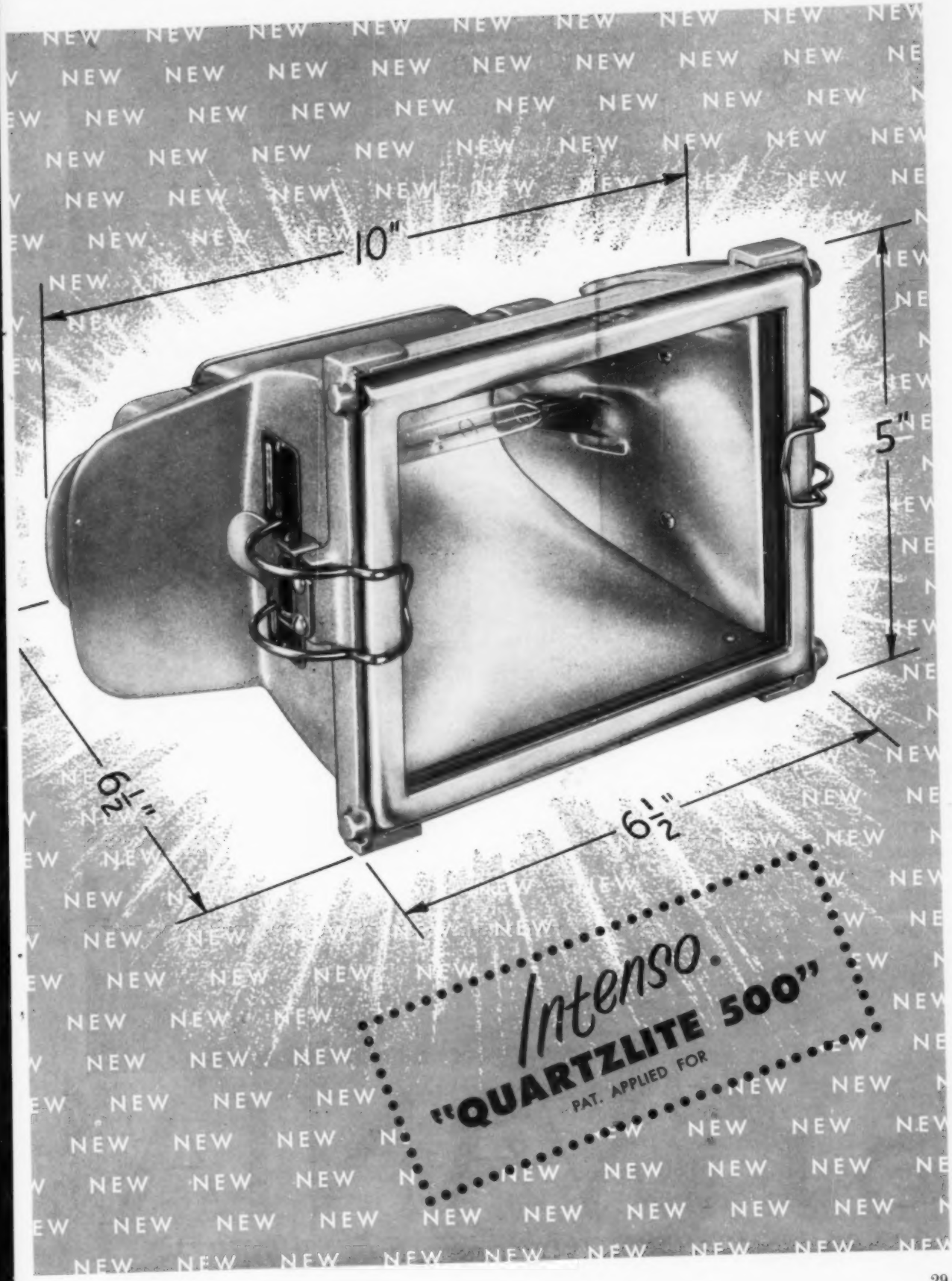
That's not all! For the first time, attractive lighting installations can be made in very small space areas – easily, economically. The special weatherproof unit design also puts light where you want it. Its extremely sharp cutoff–in a rectangular beam spread–eliminates the usual need for beam overlap, yet provides adequate, uniform light for innumerable applications indoors and out.

For increased lighting efficiency in Industry • Business • Recreation • Transportation, buy or specify the versatile *Intenso* "Quartzlite 500"... ideal for signboards, displays, outdoor sports, building security, mobile equipment, storage areas and many other uses.

WRITE TODAY FOR COMPLETE DETAILS

Sold through franchised distributors only

APPLETON®
electric company
1701 Wellington Avenue, Chicago 13, Illinois


10"
5"
6½"
6½"
Intenso
"QUARTZLITE 500"
PAT. APPLIED FOR

Ever notice homogenized milk—its clean uniformity? Sylvania engineers have taken the same principle and applied it to *light*. They have *homogenized* the phosphors in fluorescent tubes. And the result? Greater, more uniform brightness!

This is one reason why *Sylvania fluorescents deliver up to 14% more light than other brands*. Consistently! In *maintained* brightness alone every 100 Sylvania tubes give you as much light as 108 ordinary fluorescents! Hour after hour after hour!

Sylvania fluorescents last longer, too. Most fluorescents have soldered tube-to-base points. Sylvania *welds* them. Corrosion problems are eliminated, replacements reduced, maintenance costs cut!

Insured to perform better! And only Sylvania fluorescents are backed by the *exclusive* Sylvania "Light Insurance Policy." Your greatest assurance of lower TCL (Total Cost of Lighting), which means cost of lamp plus power plus maintenance. Sylvania fluorescents are *guaranteed* to perform better, in your opinion, than the brand you are using—or your money back!

These are just a few examples of consistent Sylvania leadership in lighting. Let your Sylvania representative show how *you* can get more light for less money. Call him, or write us: Sylvania Lighting Products, a Division of Sylvania Electric Products Inc., Dept. 61, 61 Boston Street, Salem, Mass. In Canada: Sylvania Electric (Canada) Ltd., P. O. Box 1190, Station "O," Montreal 9.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

(*Continued from page* 16A)

A recent announcement by John A. McDougall, vice-president of Revere Electric Manufacturing Co., Chicago, Ill., named **Edward H. Reed** as manager of the new Railroad and Industrial Lighting Sales Department.

Russell A. Gilbert has been named manager of the Consumer Products Division, Silvray Lighting, Inc., New York City. In his new position, Mr. Gilbert will be responsible for the coordination of marketing and sales for the company's line of consumer lighting products.

The Edwin F. Guth Co., St. Louis, Mo., has announced the appointment of Chassaing Brothers—Lighting as their new lighting sales agents for eastern Missouri, including greater St. Louis, southern Illinois and Paducah, Ky. The lighting sales company is headed by **Brooks and Joseph Chassaing.**

Norman Davis, Davis Sales Co., St. Paul, Minn., has been named as a sales representative for the Duray Fluorescent Manufacturing Co., Chicago, Ill. Mr. Davis will cover the Minnesota, North Dakota and South Dakota territory.

Three new regional sales representatives have recently been added to the staff of LAM Inc., Wakefield, Mass. **Joe E. Pearce & Associates,** Indiana, will operate out of Indianapolis; **Hans K. Rosenthal Co.,** with headquarters in Philadelphia, will handle the eastern Pennsylvania, Delaware and southern New Jersey territory and **Jim Shirreffs Co.** will cover most of Southern California.

The appointments of **Kenneth G. Peck** and **Howard W. Stentz** as general manager and general sales manager, respectively, of the Wide-Lite Corp., Houston, Texas, were recently announced.

Milton Weiner, sales manager of the Western Lighting Corp., Los Angeles, Calif., has announced the appointment of **Gabriel Brody** as a lighting sales engineer for the Southern California area.

The promotion of **Keith E. Hunt** to manager of the Lapeer sales district of The Detroit Edison Co., Detroit, Mich., was recently announced by Arthur L. Lane, manager of the company's southeastern Michigan sales division. Prior to assuming his new responsibilities, Mr. Hunt was assistant manager of the Monroe sales district.

Deaths

L. O. Bradshaw, Mississippi Chapter.
Eri A. Champlin, New England Section.
Harold R. Rogers, Michigan Section.

FIRST Lighting and Wiring Laboratory at a home economics school is being established at Woman's College School of Home Economics, Greensboro, N. C., through the leadership of Dean Naomi G. Albanese (center) with the cooperation of Virginia Electric and Power Co., Carolina Power and Light Co. and Duke Power Co. In addition to being used as a classroom, the laboratory will be available to builders, architects, decorators and electrical contractors for seminars, conferences and workshop meetings. Here, at a meeting discussing the formation of the laboratory, are, left to right: Professor Madeline B. Street; Roy A. Palmer, Duke Power Co.; Dr. Albanese; W. J. Burton and J. A. Lowe, both of Duke Power Co.

NEW MEMBERS

At the meeting of the IES Council Executive Committee on April 20, 1960, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Member:

*Pentecost, P. L., Alabama Power Co., Gadsden, Ala.

Associate Members:

Harris, M. D., Maxwell Air Force Base, Ala.
Hulsey, W. R., Light & Lamp Wholesalers, Birmingham, Ala.
Shelley, R. P., Delta Electric Supply Co., Andalusia, Ala.

ALAMO SECTION

Associate Members:

Alterman, William, Nathan Alterman Electric Co., San Antonio, Texas.
Reid, J. G., Allen Electric Supply Co., Temple, Texas.

ARIZONA SECTION

Members:

Hartley, B. H., P. O. Box 4381, Phoenix, Ariz.
*Morairty, R. F., Arizona Public Service Co., Buckeye, Ariz.

Associate Members:

Haag, Robert, Arizona Public Service Co., Phoenix, Ariz.
Pooler, M. A. Jr., General Electric Co., Phoenix, Ariz.
Russell, James M., Jr., Arizona Public Service Co., Phoenix, Ariz.

ARKANSAS CHAPTER

Member:

Hawn, R. H., Wittenberg, Delony & Davidson, Inc., Little Rock, Ark.

Associate Members:

Byles, B. A., Westinghouse Electric Corp., Little Rock, Ark.
Johnson, W. E., Sylvania Electric Products, Inc., Little Rock, Ark.
Keathley, L. C., Dorsey Electric Supply Co., N. Little Rock, Ark.

ARK-LA-TEX CHAPTER

Member:

*Madden, R. D., Southwestern Electric Power Co., Shreveport, La.

ARROWHEAD CHAPTER

Associate Members:

Hicks, James, Southern California Edison Co., San Bernardino, Calif.
Painter, H. K., Alec Fergusson—Electrical Contractor, Rialto, Calif.
Thomas, V. C., California Electric Power Co., Palm Springs, Calif.

BLUENOSE CHAPTER

Associate Members:

Cullinan, G. J., F. C. O'Neill & Associates, Halifax, N. S.
Mitchell, R. D., Northern Electric Co. Ltd., Halifax, N. S.
Morgan, F. S., Amalgamated Electric Corp., Bedford, N. S.
Napier, P. G., 5 Parker St., Halifax, N. S.

BRITISH COLUMBIA SECTION

Members:

*Anderson, A. M., B. C. Electric Co. Ltd., Vancouver, B. C.
*McGregor, Dorothy, B. C. Electric Co. Ltd., Vancouver, B. C.

(*Continued on page* 32A)

WARM WELCOME to guests at Edgewater Beach Hotel, Chicago, is offered by row of twelve 1000-watt quartz infrared lamps mounted over hotel entrance. In addition to providing warmth and light, the installation will melt snow and ice, evaporate water puddles. First guests to enjoy the benefits of the installation were about 1000 delegates to Edison Electric Institute Annual Sales Conference, held at the Edgewater Beach, April 4-6.

(*Continued from page* 31A)

CAPITAL SECTION

Member:

*Woody, R. P., U. S. Post Office Dept., Office of Research & Engineering, Washington, D. C.

Associate Member:

Jenkins, A. L., Architect of the Capitol, Washington, D. C.

CENTRAL FLORIDA CHAPTER

Members:

*Edwards, H. R., Hughes Supply Inc., Daytona Beach, Fla.

*Hill, K. H., P. O. Box 217, Mt. Dora, Fla.

CENTRAL ILLINOIS CHAPTER

Associate Members:

Bednara, L. E., Hub Electric Supply, Inc., Peoria, Ill.

Hamilton, J. L., Hamilton Engineering Co., Peoria, Ill.

Homola, R. S., Hub Electric Supply Inc., Pekin, Ill.

CENTRAL KANSAS CHAPTER

Associate Member:

Joyce, J. D., 218 W. Central, El Dorado, Kans.

CENTRAL NEW YORK SECTION

Members:

*Britt, E. D., George Logan & Co., Syracuse, N. Y.

Nord, O. C., General Electric Co., Utica, N. Y.

Associate Member:

Streb, T. P., Westinghouse Electric Corp., Syracuse, N. Y.

CHICAGO SECTION

Members:

*Allen, R. L., Westinghouse Electric Corp., Chicago, Ill.

*Levine, A. S., Sola Electric Co., Chicago, Ill.

*Marriett, F. J., Benjamin Electric Mfg. Co., Des Plaines, Ill.

*Walther, R. W., 1045 Fair Oaks, Deerfield, Ill.

Associate Members:

Barkley, T. J., General Electric Co., Chicago, Ill.

Bees, P. R., Multi Electric Mfg. Inc., Chicago, Ill.

D'Voret, S. R., Modern Light & Equipment Co., Chicago, Ill.

Farrell, B. J., Jefferson Electric Co., Bellwood, Ill.

Glass, Geoffrey, American Louver Co., Chicago, Ill.

Pazulinec, George, Jr., Modern Light & Equipment Co., Chicago, Ill.

Salvitti, L. J., Jefferson Electric Co., Bellwood, Ill.

Schram, F. P., Compco Corp., Chicago, Ill.

CHINOOK CHAPTER

Member:

*Hague, M. I., Lavan Lighting Equipment Ltd., Calgary, Alta.

CLEVELAND SECTION

Members:

*Jones, V. W., General Electric Co., Nela Park, Cleveland, Ohio.

*Warner, G. K., Greene & Warner, Cleveland, Ohio.

*Wey, R. C., Ohio Power Co., Canton, Ohio.

Associate Members:

Bajec, J. R., Cleveland Electric Illuminating Co., Cleveland, Ohio.

Billings, L. R., General Electric Co., Nela Park, Cleveland, Ohio.

Kunz, J. B., Rohm & Haas Co., Cuyahoga Falls, Ohio.

Wright, J. F. Jr., Firestone International Co., Akron, Ohio.

CONNECTICUT SECTION

Members:

Denniss, G. A., The Superior Electric Co., Bristol, Conn.

Hubbard, Allen, Hubbard, Lawless & Blakeley, New Haven, Conn.

Associate Members:

Barlow, E. L., Belding Hemminway Co., Putnam, Conn.

Deming, B. G., The Superior Electric Co., New York, N. Y.

Hibbert, R. F., The Polycast Corp., Stamford, Conn.

Iovino, J. T., Olschan Electric Supply Co., Bridgeport, Conn.

Loucks, J. H., Main Street, Stepney, Conn.

Mustone, J. J., 119 Lambert Ave., Meriden, Conn.

Powell, Michael, B. M. Tower Co., Bridgeport, Conn.

Reilly, R. W. Sr., Southern New England Telephone Co., New Haven, Conn.

Vance, F. G., Olschan Electric Supply Co., Bridgeport, Conn.

Worth, D. A., 157 Old Highway, Wilton, Conn.

Student Member:

Thompson, B. D., Yale University Drama School, New Haven, Conn.

CORNHUSKER SECTION

Associate Members:

Getman, R. E., 210 Frances Bldg., Sioux City, Ia.

Keyes, C. A., Graybar Electric Co., Inc., Sioux City, Ia.

DIABLO SECTION

Member:

*Spence, A. V., 2109 Roosevelt Ave., Berkeley, Calif.

Associate Members:

Baldwin, Carl, Baldwin & Baldwin, Walnut Creek, Calif.

Lewis, J. R., Aerojet General Nucleonics, San Ramon, Calif.

Omstead, F. R., Lighting Dynamics Inc., San Francisco, Calif.

Smith, W. S., Prescolite Mfg. Corp., Berkeley, Calif.

Sweeney, D. D., Walnut Creek Electric Co., Walnut Creek, Calif.

Williams, C. J., Charles J. Williams Co., Oakland, Calif.

EASTERN NEW YORK SECTION

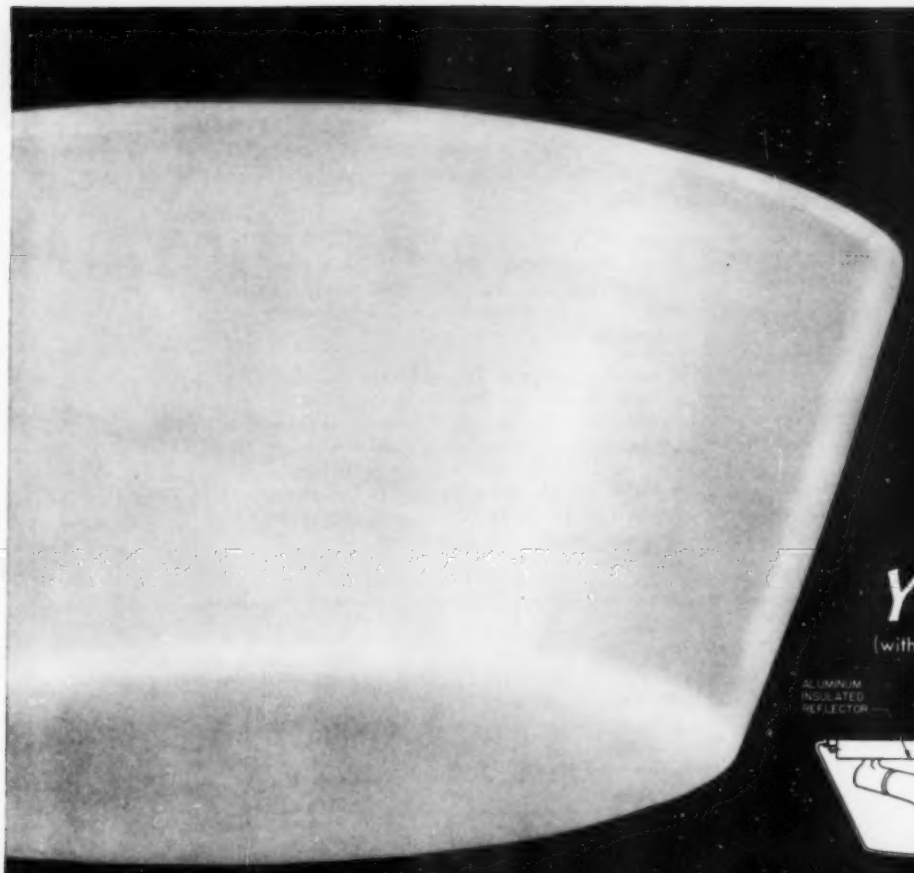
Associate Members:

Marsella, A. P., Upstate Lighting Fixture Sales, Syracuse, N. Y.

(*Continued on page* 36A)

Watch for June IE

See page 294 for details on valuable office lighting material scheduled for June ILLUMINATING ENGINEERING. In addition to first revised recommended practice since new footcandle levels were established, supporting editorial material will be published with "IES Recommended Practice for Office Lighting."



Yukon**

(with oblique sides)

PERFECLITE *Flush-To-Ceiling Fixture Designs*

Klondike*

- **They're Literally All Glass, All Light . . . Have That Built-In Look Without Recessed Construction**
- **Due To A Unique Patented Hanging Device, Nothing Projects — No Metal Shows**
- **Bowls Open On Concealed Disappearing Pivot Hinges . . . Are Secured In Place By A Simple Twist Of The Wrist**

Both the Klondike and Yukon feature interior construction of 20 gauge steel — a baked white enamel steel reflector with heavy aluminum foil reflecting surface and multiple porcelain sockets equipped with #18 AF leads for direct connection to Types R, TW or any 60° C. rated wire.

For further information on either unit, mail the attached coupon today!

*Patented **Patent Applied For

Units are Underwriters' Laboratories, Inc., approved

THE PERFECLITE COMPANY

1457 EAST 40th STREET CLEVELAND 3, OHIO

Please send me the Perfeclite Data Folder 59-C.

NAME _____

ADDRESS _____

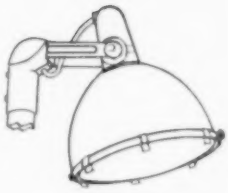
CITY _____ STATE _____

Revere Outdoor Lighting Report

Lighting an automobile sales lot

The Problem: To illuminate a long, deep sales area so that cars, signs, and buildings would attract attention and look more appealing to passers-by.

The Answer: Five poles, each mounting ten Revere No. 7403 *1000-watt* mercury floodlights on a No. 217-ZA bracket, were installed to provide the high level of lighting desired. Ten No. 3510-AL Revere Par Lamps are also mounted on each pole 10 feet above grade to highlight the color and beauty of the cars and create more sales appeal.

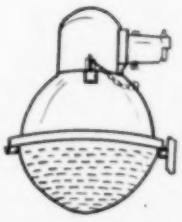


No. 7403 Floodlight

Lighting a city street

The Problem: To provide a lesser traveled secondary street with uniform, moderate-level lighting, in the most efficient, economical way possible.

The Answer: Revere Star-Lux incandescent street lighting luminaires were installed on converted concrete poles to provide efficient lighting at low cost. The Star-Lux uses up to 10,000 lumen incandescent lamps or 250 to 400-watt mercury lamps to provide any of the five standard A.S.A.-I.E.S. distribution patterns.

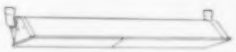


No. 2311-A/2363
Star-Lux Luminaire

Lighting a poster board

The Problem: To assure greater night visibility of an advertiser's poster board sales message by providing higher level, more uniform illumination.

The Answer: Revere Fluoresign outdoor luminaires with very high output fluorescent lamps were installed to give the high level of illumination desired. Reflector and lamp assembly may be positioned at any desired angle for uniform light distribution. Lamps give 10 times the rated life of incandescent types. Fixtures are unobtrusive, too.



Fluoresign Luminaire

Write for Revere's complete catalog of outdoor lighting equipment

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

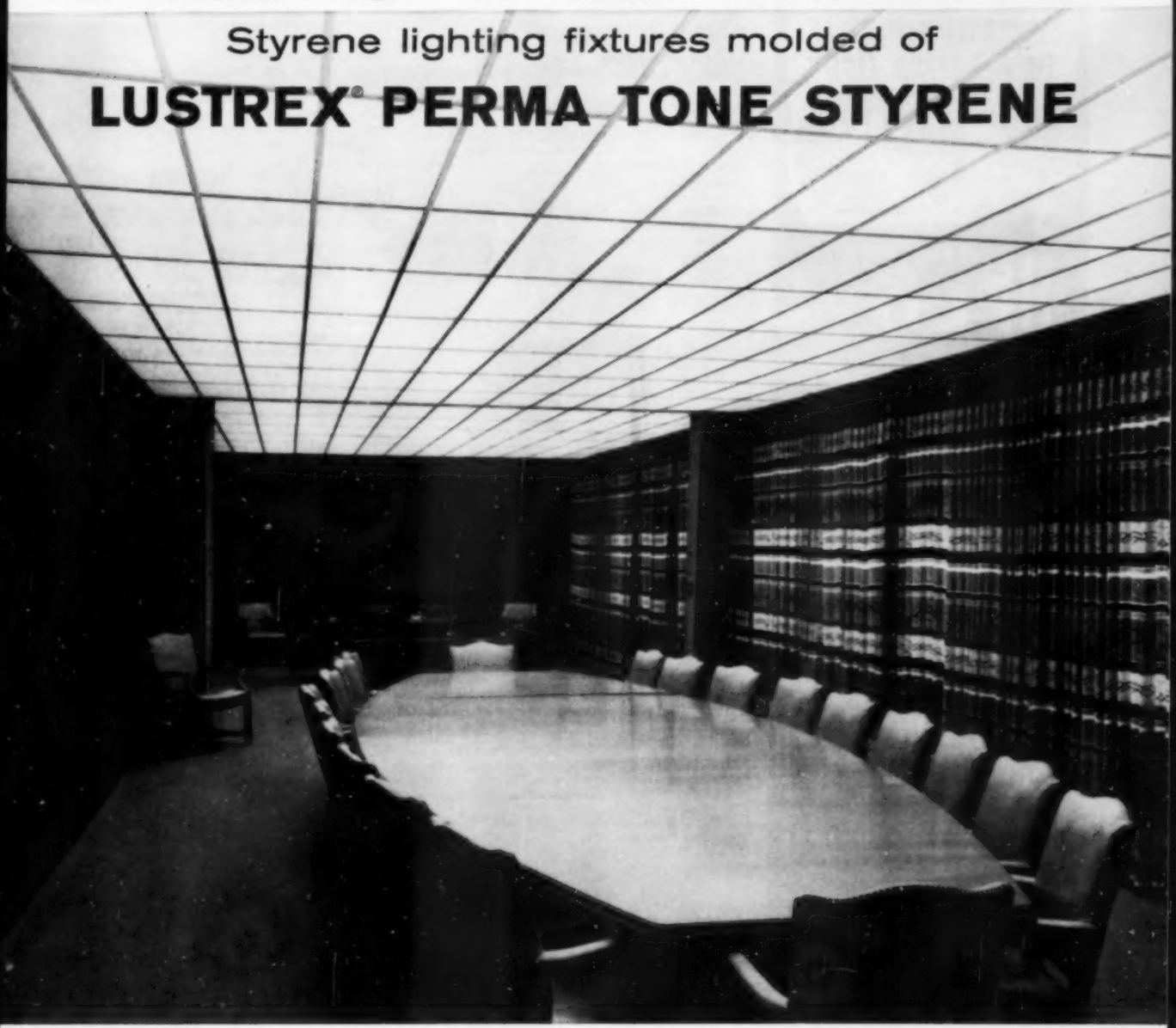
Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 31, Illinois

Available in Canada thru Curtis Lighting, Ltd., Leaside, Toronto, Ontario

ABOVE ALL:

Styrene lighting fixtures molded of

LUSTREX® PERMA TONE STYRENE



More Lustrex perma tone is used for lighting fixtures than any other ultraviolet light-stabilized styrene.

In clear white and a complete color range, it exceeds IES-NEMA-SPI joint specifications for ultraviolet light-stabilized styrene. With perma tone you can create low cost large areas of illumination with good diffusion, dimensional stability, and uniform light distribution.

New Impact Lustrex perma tone provides extra toughness and flexibility for snap-fitting to metal parts, high resistance to abnormal abuse, lighter weight through thinner walls. For free technical report on both regular and impact Lustrex perma tone styrene, including accelerated aging test results and other valuable data on styrene in lighting fixtures, write to Monsanto Chemical Company, Plastics Division, Room 727, Springfield 2, Massachusetts.

Monsanto®

LUSTREX: Reg. U.S. Pat. Off.

MONSANTO ORIGINATOR IN **PLASTICS**

PUT YOURSELF IN A *BETTER LIGHT* WITH metco Lighting

HI-LO WRAP-AROUND

ONE-PIECE Diffuser with a High Intensity Clear FLAT PRISMATIC Lens AND Low Brightness Sides!

Only 3⅛" deep (including diffuser), you get new, modern appearance with increased down lighting and glare-free, low surface brightness. Light is emitted from sides, bottom AND top with a wrap-around plastic shielding that lowers from either side.

Write today for full details and catalog sheet.

SOLD ONLY THROUGH QUALIFIED ELECTRICAL DISTRIBUTORS

METALCRAFT PRODUCTS CO., INC.
6225 State Road, Phila. 35, Pa.

(*Continued from page 32A*)

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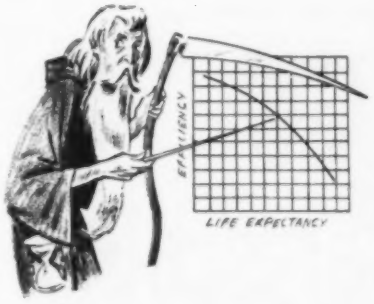
(*Continued on page 38A*)

Facts of Light!

CHAMPION Lamps

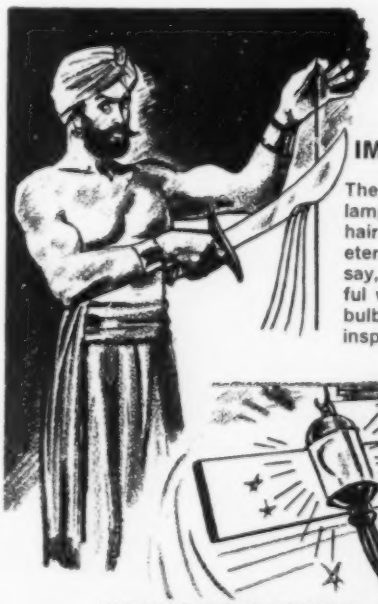
YOU SPEND NEARLY $2.50 TO OPERATE A 25 CENT LAMP

The electric power required to operate a 25 cent incandescent lamp will amount to nearly $2.50 before the lamp burns out. The efficiency with which a lamp converts electric power into usable light, then, is an important factor in considering lamp value.



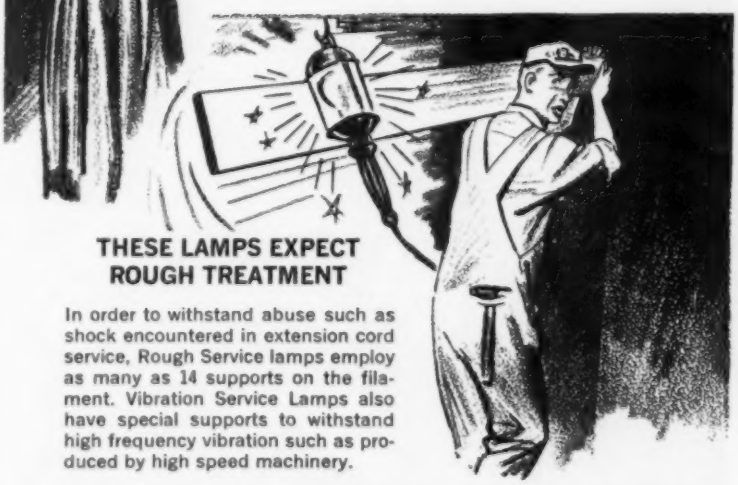
YOU CAN'T GET BOTH HIGH EFFICIENCY AND LONG LIFE IN INCANDESCENT LAMPS

General service incandescent lamps are designed so that the ratio between life and efficiency results in lowest overall lighting cost for the average installation. When efficiency is increased, lamp life is shortened. When lamp life is extended, efficiency goes down. Occasionally it makes sense to sacrifice efficiency for long life; for instance, when installing "long life" reflector lamps in inaccessible locations to minimize the high maintenance costs.



SPLITTING HAIRS IS IMPORTANT IN MAKING LAMPS

The filament wire in some incandescent lamps is only 1/5 the diameter of a human hair. A variation of only 1% in this tiny diameter can affect lamp life by 25%. Needless to say, it takes precision equipment and careful workmanship to insure that millions of bulbs a year pass Champion's rigid quality inspections.



THESE LAMPS EXPECT ROUGH TREATMENT

In order to withstand abuse such as shock encountered in extension cord service, Rough Service lamps employ as many as 14 supports on the filament. Vibration Service Lamps also have special supports to withstand high frequency vibration such as produced by high speed machinery.

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This is typical of the quality and ruggedness you find in Guth Brascolite Incandescents. They're built for rugged duty PLUS optimum and long life lighting performance!

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(*Continued from page* 37A)

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(*Continued from page* 38A)

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(*Continued on page* 40A)

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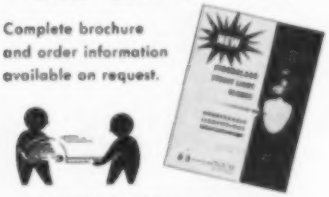

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(*Continued from page 39A*)

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Stein, H. J., Northern Electric Supply Co., Duluth, Minn.

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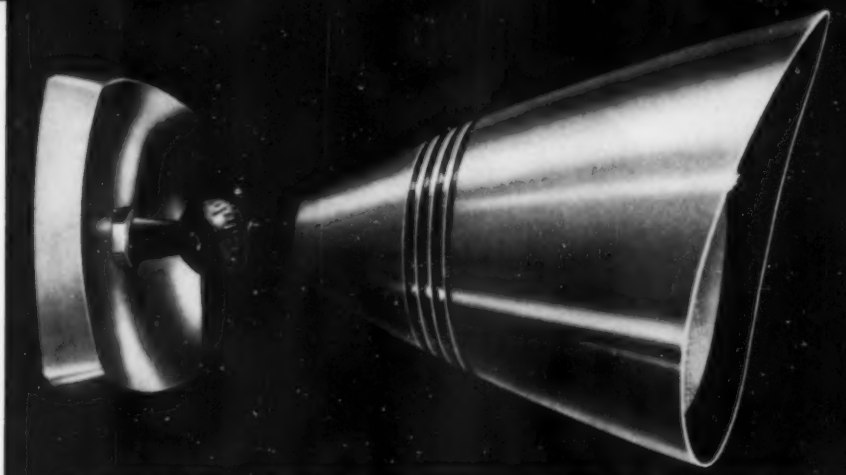
Poulson, W. E., Graybar Electric Co., Salt Lake City, Utah.

(*Continued on page* 43A)



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- The Award Series is now on display at your STONCO distributor. Look for it.
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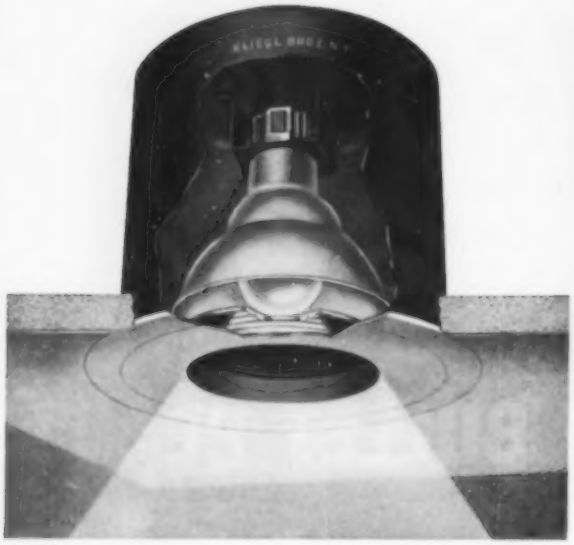

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Designed Optics . . . properly controlled general area illumination from a concealed lens downlight. Using a specially designed hidden lens support cone and a Fresnel Lens with black painted risers, Kliegl Regressed Lens Downlights give a soft illumination without side glare or surface brightness.

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#220

#220—For Bulb-Tee, Tee Bars, other flanged structurals.

- √ Cuts Labor Costs
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- √ Fully Adjustable — from 1¼" to 2⅜"

New #220 hangs fixtures, metal raceways, troughs, outlet boxes, etc.—faster and easier—on bulb-tee, tee bars, and other flanged structurals. Try them on your next job!

HANG FIXTURES FASTER ON INVERTED "T" BAR ACOUSTICAL CEILING WITH

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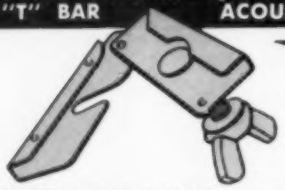

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The #210 SNAPEE Grid Hanger snaps onto "T" bar, slides into desired position and locks securely at right spot. Mount fixture in position, fasten wing nut, and the job's done.

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(Continued from page 41A)

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WORLD'S HIGHEST SINGLE LIFT LOCK FEATURES Servisafe POLES

Floating guard boom and lock (background) at T. V. A.'s Wilson Dam, Florence, Alabama

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To expedite barge traffic through Wilson Dam, a new 110 x 600 foot single lift lock has been installed by the Tennessee Valley Authority. This giant lock, capable of handling an entire tow in a single lockage, will operate around-the-clock. A high level of illumination is required therefore for night operations. In addition, lighting efficiency must be maintained year-round. Thompson "Servisafe" Poles met the specification for this job and 80 units were installed along the lock, its floating guard boom and a new steel bridge over the lock.

"Servisafe" poles permit fast, safe, all-weather luminaire servicing *at ground level.* They also reduce maintenance costs because a single unskilled man can quickly relamp and clean a pole-mounted light without hazard or costly auxiliary equipment.

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For details on "Servisafe" poles, write today for BULLETIN PWB-59.

T-E

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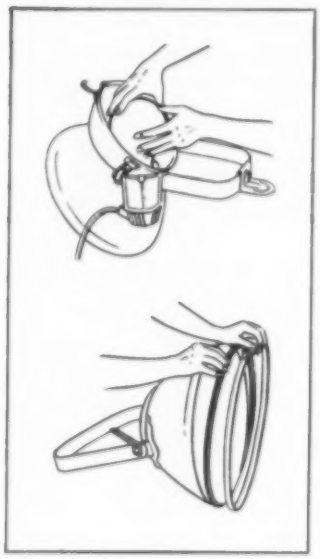
P. O. BOX 873-K • CLEVELAND 22, OHIO

New Steber Series 5000—Rear Lamped Floodlights—are designed to meet NEMA Specifications FL6-210, Group B, Types I, II, III, IV and V. They accommodate G-48, 1500 watt, PS-52, 750-1000-1500 watt incandescent and 400-700 watt Mercury Vapor lamps.



In addition to "rear-lamping," Series 5000 floodlights include these exclusive Steber features:

1. Genuine Silicone gasketing at all critical points
2. Finned, cast aluminum neck and cap for maximum heat dissipation
3. Shielded condensate drain
4. Removable thermal shock and impact-resistant lens
5. Rear section clips to trunion bracket, leaving both hands free for faster, safer servicing
6. Positive grounding—both during operation and servicing

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The well-known Steber "shipment within 16 working hours" policy applies to Series 5000 Floodlights, as well as to all other Steber lighting equipment. No need to wait 6 to 8 weeks or longer for "rush" jobs—specify Steber and your delivery problem is solved.

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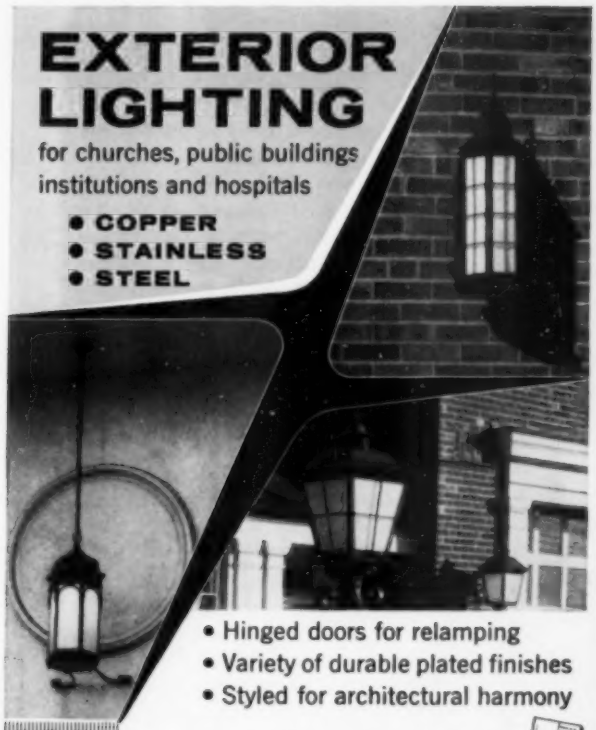

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- Styled for architectural harmony

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1-60A

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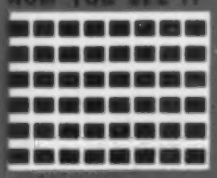

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